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Europe

Commission of the European Communities:
First Report on the State of Science and Technology in Europe

EC Issues First Report on State of Science, Technology in Europe

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[Text]

Foreword

"After years of uncertainty and even hostility towards new technology we are witnessing a change in public attitudes in Europe today: the need for scientific progress finds a greater acceptance again, and the success of European science is contributing to a new self-confidence. We no longer respond to the American and Japanese challenge in a defensive way.

"This development was undoubtedly necessary because of the fact that technology has become a decisive element in world competitiveness. It is obvious that the scientific and technological potential of an economy largely determines its capacity to shape its own destiny. Only by developing this potential further can the European Community maintain its autonomy and an ability to succeed by its own efforts.

"In spite of considerable successes, Europe still has a significant gap to fill in a number of high technology sectors. These are precisely the sectors which will determine our competitiveness in the decades to come: information technology, bio-sciences, new materials.

"If Europe does not succeed in reducing its technological dependence in these fields over the next few years, the Community's internal market will also remain fragmented. A strong Technology Community is an indispensable element in our strategy for 1992, particularly because of its link with the liberalization of public procurement.

"This is where the present report should help to show the way. First of all, it is intended as an assessment of European science and technology to date. But it also identifies our technological needs for the future, as well as opening up a discussion on the best means of carrying them out.

"There is no reason for the European Community to be reticent either in terms of science and technology or in any other field. There is nothing to fear in comparing our merits with those of our partners and competitors in the world market. The Community actually seems to be at a political and economic stage which should allow it to give technology the role which it ought to have today as we approach the threshold of a new century."

Karl-Heinz Narjes, Vice-President of the Commission of the European Communities

Highlights

1. This report is a first response to the request of the European Parliament for regular reviews by the Commission of the state of science and technology in Europe.

It draws on wide-ranging sources of information and assessment, notably: the Parliament itself, the science and technology administrations in the member states, the committees specifically established to advise the Commission on research requirements, the views of the independent evaluation panels on Community programs, systematic monitoring of the scientific and technical press and scientific meetings, as well as ongoing work in other international organizations.

The Commission intends to update the report during 1989. Thereafter it should be published at two-year intervals.

2. The main aim of the report is to provide a factual basis for further reflection, both inside and outside the Community institutions, on Europe's needs in science and technology and how best they can be satisfied. It does not, however, attempt to identify at what level or in which framework at national or at transnational level action in specific fields could most beneficially be taken.

3. The tentative picture emerging from this first report can be summarized as follows:

(i) A good deal has already been done to improve the European situation by increased efforts in spending on research and development and in improving industrial performance through innovation. But the efforts are still unbalanced and fragmented. Three Member States (Germany, France and the United Kingdom) account for three-quarters of total spending on R and D in the Community; and regional variations are acute. Cooperative transnational actions (Community programs, EUREKA [European Research Coordination Agency], COST [European Cooperation in Science and Technology], ESA [European Space Agency], CERN [European Center for Nuclear Research], etc) account for only a small percentage of the total research effort:

(ii) European efforts are in case well below those of our major competitors (the USA and Japan) who are both spending more and also taking action to remedy their own weaknesses. Europe's position is also threatened by the new efforts of emerging science and technology powers (the NICs in particular);

(iii) Europe faces three main challenges:

- To increase its capacity to develop and pursue, where necessary, its own technological and economic options;
- To strengthen its international competitiveness, especially in those fields which will take on increasing importance in the future;
- To meet the social need for improved quality of life.

(iv) Europe has the resources to meet these challenges. It is rich in scientific talent and organizational ability. And in its present economic situation it can afford to invest more in R&D. The question is how to get the best out of these resources and in which areas to focus the effort.

(v) Getting the best out of European efforts entails addressing a series of issues: ensuring that science and technology are understood and accepted at all levels of European society; overcoming imbalance and fragmentation by better coordination and by ensuring an adequate basis for technological progress in the less-favored countries and regions; encouraging the spread of technology skills throughout society; attracting more private sector finance and facilitating the diffusion of technology throughout industry; encouraging the links between industry and universities; as well as exploiting the scope for international collaboration in those areas where there are evident mutual benefits.

(vi) As far as research areas are concerned, the report highlights five areas of major relevance to the European economy:

- Information technology and telecommunications—a particular research effort is needed to improve the situation of the European semiconductor industry.
- New materials and technologies for use in manufacturing industry—superconducting materials are particularly promising.
- Aeronautics, where Europe faces a particular competitive challenge.
- Biology and biotechnology which offer the prospect of major transformations in industry and agriculture as well as in the medical field. Specific efforts, however, are needed on basic plant biology, gene-mapping, neurobiology and biotechnology applications.
- Energy, where Europe remains highly dependent on outside sources of supply—fusion is important for the longer-term and carefully targeted research on new and renewables and energy saving technologies in the shorter-term.

In terms of the quality of life there are major research needs in the fields of environment, health research and industrial, road and nuclear safety. In environment some of the research requirements have a global dimension. Europe has the capacity as well as the need to make a major contribution to the study of Global Climate change.

Underpinning these efforts in specific fields Europe must sustain and develop its capacity in basic research to provide the seedcorn for new technological openings.

4. There follow summaries of each chapter to the report.

I. Science and Technology and Europe's Economic and Social Needs

5. Despite substantial progress in recent years, Europe remains weak in a number of the science-based sectors which are growing rapidly world-wide. This specific weakness reflects a **technological dependence** in key areas. Electronic components is a particularly important case.

The more traditional sectors of manufacturing industry continue to account for higher shares of GDP than in the United States and Japan. Some of them have made real progress in modernizing through the application of new technologies. Textiles is one example. Others, such as the paper and board processing industry, or parts of the machine-tool industry have been less successful. Even those that have radically improved their position through automation and innovation (eg. automobiles) face increasing competition. One successful company strategy in a number of industries has been to seek the capture of the top-end of the market through technology.

Major efforts continue to be needed to improve the technological position of European industry and to seize the opportunities offered by scientific and technological advance. Progress towards completion of the Internal Market will help to create the right framework conditions. But it needs to be accompanied by specific efforts in the RTD field.

6. Improvement in the **quality of life**—the environment, health-safety—are also increasingly important concerns throughout Europe. Developments in science and technology are opening up new opportunities for tackling these problems in an effective and economic manner.

7. Europe needs a **broadly-based scientific** and **technological capability** to respond to the twin needs of increased competitiveness and a better quality of life. This means being able to choose and to develop its own technological options where this seems appropriate. A fundamental research capability is particularly important. Fundamental research is increasingly recognized internationally as the provider of new openings and ideas and a key factor in conditioning the pattern of economic and social development longer-term.

8. The acquisition and maintenance of such a broadly-based scientific and technological capacity is, however, increasingly expensive: science is developing at an accelerating pace with ever shorter periods of time over which to depreciate investment in R&D. This underlines the importance of the most cost-effective solutions to the organization of R&D, avoiding fragmented efforts. It also means that the broadest possible market is needed for the commercialization of the products of research and development.

II. European Science and Technology in a Comparative Perspective

9. European efforts have to be set against the **changing international environment.** Our main competitors (the United States and Japan) have been making their own adjustments to changing needs while new players are

becoming increasingly important or could be so over the coming years (the NICs, the Soviet Union, China).

10. European spending on R&D is still well below that of the United States in absolute terms and below the United States and Japan as a share of GDP. U.S. spending in volume is 1.75 times that of the Member States of the European Community combined, and research intensity (R&D spending as a proportion of GDP), is only 1.9 percent in the Community compared with 2.8 percent in the United States and 2.6 percent in Japan. Germany alone has a research intensity (2.8 percent) comparable to Europe's competitors. Even when defense spending is excluded United States expenditure remains significantly higher than the European average.

In both the United States and Japan business also invests and carries out more of the R&D than in Europe.

Both the United States and Japan have larger numbers of research scientists and engineers in their labor forces; the growth in Japan has been striking.

The United States

11. The high level of **defense R&D** in the United States, half of which is contracted out to industry, is a potent factor in mobilizing resources. The precise level of spin-off to the civil sector from military R&D in general and from SDI in particular, is hard to assess. But there have been undoubted major benefits in the fields of materials, aircraft engineering, vehicle technology, computer technology and systems engineering. The shift during the 1980s of much military R&D towards development work tailored to the needs of more fundamental and applied research has, however, raised some concern in the United States about reduced industrial impact.

12. This has coincided with worries about the **competitiveness of U.S. industry** and U.S. technological dependence, notably vis—vis Japan. The Reagan Administration has taken initiatives to encourage American industry to cooperate in the face of this challenge and to increase the transfer of knowledge from Federal programs to industry. These have been combined with a more restrictive approach to the wider availability of the results of research.

13. A third concern in the United States is the prospect of a **shortfall of perhaps 500,000 scientists and engineers by 2010** because of demographic trends and the pattern of university enrolment. One issue is the encouragement of foreign students (especially those from the Pacific Basin) to stay on in the United States after graduation. At the post-doctoral level there are likely to be increased pressures to "poach" skilled R&D personnel from abroad, especially from Europe.

Japan

14. The importance of **basic research** continues to be recognized in the United States: it is the only sector of Federally-funded civil R&D to have increased in recent years. In Japan, where economic success has been founded essentially on the absorption and transformation of foreign technology, efforts are now under way to build up a capacity in basic research, reflecting a perception that this will be essential in opening up new technological options for Japan in the longer-term and enabling it to stay one step ahead. Already Japan has strengths in, for example biotechnology, new materials and neuro-computing.

This interest in basic research, and the need to respond to concern about the closed nature of the Japanese science and technology system, has led to new openings in international collaboration, including the Human Frontier Science Program.

Emerging Science and Technology Powers

15. The most dynamic NICs are planning a substantial growth in R&D spending and strategies for the development of large cadre of highly qualified personnel, as they themselves face challenges from other industrializing countries. Korea in particular is making efforts in this direction. Other emerging sciences and technology powers include Taiwan, India, Brazil and Israel.

China is making particular efforts to improve its science and technology capability and major research programs have been launched.

Developments in the Soviet Union, which was the largest scientific establishment in the world and significant achievements in, for example, aspects of space technology, mathematics and theoretical physics, will depend heavily on the success of the policy of restructuring (perestroika) and its impact on the deployment of scientific resources to the civil economy.

III. Mobilizing Europe's Resources

R&D Spending (public and private)

16. Within Europe there are major **national** differences in levels of investment in R&D; in the relative importance of the public and private sectors; and in the distribution of resources among research sectors.

Three countries (Germany, UK and France) account together for over three-quarters of total public and private spending on R&D in the European Community. Germany has by far the highest research intensity and the highest number of researchers in its labor force. Industry also plays a bigger role in both the financing and execution of R&D in Germany than elsewhere. In the less favored Member States the public sector is by far the predominant source of R&D finance.

17. **Regional** disparities are larger still. The gap in R&D intensity is of the order of 12:1 between the Member States themselves and much greater at a sub-national level. This technology gap between the developed and the less-favored regions is much wider than the economic gap.

Government Policies and Public Funding

18. In the majority of Member States public R&D budgets have grown during the 1980s, although there has been some recent tailing off.

19. **Defense** R&D is particularly important in the United Kingdom (around 50 percent of the total public finance) and France (34 percent), and to a lesser extent Germany (12.5 percent). Elsewhere the shares are much smaller and in some cases negligible. The wide differences in defense R&D make coordination of national policies on dual-use technologies particularly difficult.

20. Some countries give particular emphasis to the public funding of **basic research** Germany, France and the Netherlands in particular). In others, public expenditure constraints, the rising cost of basic research, increased emphasis on measurable cost-effectiveness and urgent need to improve competitiveness have led to a new emphasis on **industrially-oriented** research.

European Cooperation and Coordination

21. Transfrontier cooperation in Europe, involving industry as well as universities, has increased significantly in the past few years. The experience has been overwhelmingly positive. The Community's own cost-sharing programs have been oversubscribed, reflecting a widely felt need for collaboration, especially at a time when pressures on national budgets have been growing. The experience of EUREKA—213 announced projects involving 800 organizations, two-thirds of them industrial—is further evidence of this thirst for a transnational approach.

22. The share of the total European research effort that is handled through these cooperative ventures remains, however, small. The total cost of projects supported through the Community's programs is equivalent to about 4 percent of total estimated EC public and private spending on civil research. Even taking into account the other major European ventures—EUREKA, ESA, CERN, EMBL, etc.—the vast bulk of research continues to be financed and carried out at national level, a large share of it through national budgets.

23. The need to identify precisely where excessive **duplication** and **overlap** occur among these national efforts is pressing. Efforts are being made within CREST to improve the information base and to "confront" national policies. In the light of further progress in this forum, the Commission intends to focus particular attention on duplication and overlap in its forthcoming reports on the state of science and technology.

IV. Research Issues for the Future

24. The research needs of Europe reflect the three challenges described in Chapter I:

- To improve international competitiveness, notably in the context of the completion of the Internal Market;
- To respond to the needs of society by improving the quality of life;
- To increase the Community's capacity to develop and pursue, where appropriate, its own technological options, drawing on the opportunities offered by a solid fundamental research capability.

The following is not an exhaustive list. It concentrates on areas where particular efforts are needed to complement or to supplement ongoing or planned activities by industry and by public bodies (national and transnational).

Improving Competitiveness

25. There are significant research needs in five areas: information technology and telecommunications, industrial materials and technologies, aerospace, biological sciences and energy.

26. The European **information technology** industries are in better shape than at the beginning of the 1980s. But the negative balance of trade in IT products is large (13.4 billion US$ in 1986), reflecting dependence in the fields of electronic components in particular.

Research is needed to give Europe the capacity to master and develop the next generation of memory chips based on circuity for feature series below 0.5 micron. A significant cross-border collaborative project (JESSI) is currently under discussion among European manufacturers.

Progress is also needed in software and advanced information processing and in peripherals (flat panel displays and optical storage technologies) where Europe's position is weak.

More basic research is required on questions such as the security and reliability of computers, computer languages and machine-learning; as well as prenormative work to prepare the integration of IT systems designed for a wide range of services (intelligent banking and financial services etc.).

27. In **telecommunications** Europe's relatively favorable position could be threatened by continuing weakness in the electronic components sector, the spiralling costs of R&D and new technological and market challenges (such as the digitalization of networks, developments in broad-band networks).

Research is needed on a wide front, including better network management systems; specific electronic and opto-electronic components; new materials and software tools.

28. A significant research effort will also be required in the development, coordination and integration of technologies for the application of IT and telecommunications, including language technologies.

29. **Manufacturing industry** currently provides 30 percent of Community GNP and employs 75 percent of the industrial work force of some 41 million. A general need is to ensure the diffusion and application of available new technologies by this sector. In parallel a major research effort continues to be necessary to open up new technological possibilities for European industry and to solve particularly pressing problems. Areas of particular interest include:

- Techniques for quality control (which can cost up to 25 percent of company turnover);
- Techniques for shaping, joining and assembly;
- Surface treatment to prevent corrosion (which can cost up to 4 percent of GNP);
- Powder technology, which is a particularly large and high-value market;
- Other high-value materials, such as metal composites (already being developed for ceramic-reinforced light alloy pistons)

A concerted research effort on superconducting materials is particularly necessary. Large financial resources are being mobilized in the United States and Japan.

- Norms and standards. Prenormative work is needed in a number of areas, including lasers.

30. In **aeronautics** the European industry has had major successes, capturing (1980-1986) 23 percent of the civil and 27 percent of the military world market. But sharply increasing competition can be expected over the next 10-15 years, not only from the United States but also from Japan and industrializing countries such as Korea and Brazil. The United States remains in a particularly favorable position because of the large home market and the spin-off from military programs.

The future commercial success of the European aeronautical industry will depend heavily on advanced technology. In order to prepare for the 1990s and beyond Europe the need is for broadly-based collaborative efforts focussed on aerodynamics and flight mechanisms, materials, acoustics, computation, airborne systems and equipment, propulsion integration and design and manufacturing technologies.

31. The future market for **biotechnology** products is difficult to quantify precisely; but worldwide the biological sciences are recognized to offer the prospect of major economic and social impacts (through environmentally "clean" transformations of agricultural and industrial productivity; progress in pharmaceutical, chemistry and medical science; improved understanding of the brain, with its implications for computer design as well as its impact on psychology and psychiatry).

Four areas of research merit particular attention:

- **basic plant biology.** Without a better understanding of key structures and functions within plants it will not be possible to make significant advances in application technology;
- **gene-mapping** of complex organisms. For agriculture and industry the detailed mapping of the genes of important microbial plant and animal species is an essential complement to the work on basic plant biology. For medicine, a better understanding of the human genome is as necessary to the continuing process of medicine as knowledge of human anatomy is to its present state. This is laborious and expensive work. Major international efforts are underway. Europe has experience on which to build;
- **neurosciences,** where efforts are already under way to coordinate some national actions;
- **industrial and agro-industrial applications.** Particular research efforts will be needed by the pharmaceutical industry to maintain its good competitive position, in the face of growing competition and the cost and time-scale needed for the development of new products. Research is also needed on improved food technologies and on nutrition itself.

32. The **energy** markets are currently slack, with plentiful supplies on world markets. But Europe remains heavily dependent on third countries for supplies, particularly of oil, which is still the largest single element in the Community energy balance. There is a continuing need to ensure adequately diversified energy supply and **efficient energy use** and to reduce as far as possible the impact of energy supply and use on the environment. Two lines of research remain of particular importance:

- **controlled nuclear fusion,** which offers the prospect in the next century of an environmentally acceptable, practically inexhaustible, geographically independent source of supply. Europe is already playing a leading role;
- research on selective **non-nuclear energy technologies** and technologies for improving energy use which offer the best prospect of exploitation on a wide scale.

Improving the Quality of Life

33. Science and technology have fundamental roles to play in devising rational and effective **environmental** policies. Continuing research efforts in Europe are needed under three interdependent headings:

- understanding the basic phenomena;
- detection and interpretation of environmental changes;
- prevention.

A scientific approach to understanding the complex interactions of the many complex sub-systems (the stratosphere, the atmosphere, soil, land water, the sea) would have been unthinkable a few decades ago. But progress in basic mathematics, in analytical techniques and technologies (including remote sensing from space), together with the huge capacity to handle information through advanced computing, now makes this possible.

Some of the problems are particular to Europe in a regional sense and require European level efforts. Action is under way both through the Community programs, COST as well as EUREKA projects. Good coordination among these projects is essential. The most complex issue of **global climate** change and the "greenhouse effect," however, is an issue with truly global dimensions. Europe has the capacity to make an important contribution to the International Geosphere-Biosphere Program (Global Change).

34. In the field of **health,** Europe is faced with sharply rising health care costs (a world-wide phenomenon); a "greying" of its population, with the consequent increase in age-related diseases, and growing problems posed, in particular, by AIDs and cancer.

European research in the medical field suffers from particular fragmentation. This is an area where the value of concerted action across national frontiers has already been clearly demonstrated. The essential need is for more of the same in tackling the problems described above, as well as continuing research on medical technology.

35. In the field of industrial technologies and materials increasing attention will have to be given to **safety** issues. R&D has an important role to play in the development of common safety standards in particular for new technologies such as lasers.

The potential contribution of R&D to long-term **road-safety** through the development of the "intelligent" car and the infrastructure to support it, is also considerable. Cooperative efforts are already under way in Europe to address these issues (the DRIVE [Dedicated Road Infrastructure for Vehicle Safety in Europe] program in Community, and PROMETHEUS [Program for a European Traffic with Highest Efficiency and Unprecedented Safety] and other projects inside EUREKA). There is an obvious need for good coordination among all these projects to ensure optimal resource allocation.

36. Continuing attention will need to be paid also to work on the safety of **nuclear fission.** In addition to research on reactor safety, the safety of the fuel cycle, radioactive waste management and storage, the safety of dismantling nuclear plants at the end of their lives, a particular effort will be required to increase public confidence about **radiation protection.** This requires both research work itself and efforts by the scientific community to present the issues in a way which is accessible by the general public.

37. **Bioethics** are attracting growing attention world-wide. A particular effort is needed at Community level in particular because of the importance for the Internal Market of a harmonized regulatory environment. Ethical, societal and juridical considerations must accompany science and precede technological development.

Fundamental Research—The Essential Underpinning

38. Fundamental research is continuing to open up significant new opportunities through progress in mathematics, physics, chemistry and the earth sciences.

The theory of non-linear **mathematics**—pioneered in Europe—has pervasive applications, opening up prospects such as the all-optical computer, advanced modelling of climatic change or significant improvements in the functioning of the internal combustion engine.

In **physics** there are strong points in the European situation, but also some weaknesses: the efforts on laser science and technology, for example, are not on a par with those in the United States, despite some significant multinational efforts.

Europe occupies a good position both in **basic chemistry** and on the market for chemistry-based products. But there is a problem in recruiting a sufficient number of high quality students.

In **earth sciences** good European coordination is being assured by the European Science Foundation. In oceanography the United States is leading the field. Some aspects, such as the study of the coastal zone, the interface between the ocean and the atmosphere will be pursued through the Community's MAST program and the EUREKA project EUROMAR.

Earth observation from **space** is of major potential significance for the earth sciences.

39. Within Europe there are already several multinational ventures for the common pursuit of Big Sciences (CERN [European Center for Nuclear Research], ESO [European Organization for Astronomical Research in the Southern Hemisphere], ESA [European Space Agency], EMBL [European Molecular Biology Laboratory], ESF [European Science Foundation], etc.). There is growing collaboration amongst them, which must develop further. Increased collaboration with Community programs is also desirable so as to maximize the industrial and commercial spin-offs. **Space**research is one area of particular importance.

40. There are also outstanding questions related to access to advanced middle size research devices in Europe and

the development of expensive scientific instrumentation. Given the cost of sophisticated facilities it is not feasible to imagine that they can be available in every European country. Particular attention will be needed to provide a framework for cooperation among national teams.

V. Key Issues for Science and Technology Policy in Europe

41. Alongside the research needs themselves there are some broader policy questions of particular importance:

(i) **The imbalance of effort between fundamental and applied research across Europe**

One theme of this report is that a sound capacity in fundamental research is essential to Europe in its pursuit of technological and economic independence. This is an area where public authorities have a particularly important role. But in the funding and execution of basic research industry too has evident self-interest. In the United States much of this research is funded by industry.

(ii) **The links between industry and the universities**

These have been growing world-wide, with industry driven increasingly to tap scientific knowledge and universities driven by financial constraints. The trend is a desirable one, with two caveats: namely, that it should not jeopardize the pursuit of fundamental research in universities and that restrictions on the dissemination of research results should be minimized.

(iii) **Broadening and deepening the technology culture**

The most successful economies in recent years have been those that have sought actively to develop on a broad base the human skills required both to research, to develop, to apply and to use technology. Japan is the best example. Europe as a whole is in a weaker position. There is shortage firstly, of skilled manpower trained to use the new technologies; while the output of research scientists and engineers to develop and apply the technologies is insufficient in many countries. An added difficulty is that the brightest and the best in Europe are often attracted across the Atlantic. Particular attention will be needed to ways of increasing the supply of skills and to provide an environment in Europe that is attractive to highly qualified scientists. This means removing the barriers to mobility of research workers between European countries.

(iv) **Public acceptability of science and technology**

Public concern about new technologies is often based on fear of the unknown. It is important both for democracy and for the pursuit of scientific knowledge that popular understanding of the issues should be improved. This will help to ensure that informed choices are made and a sound regulatory environment established. The information effort in many European countries is still inadequate.

(v) **Encouraging the private sector to invest more**

Industrial investment in R&D is still too low in many European countries. The venture capital markets are insufficiently developed in many countries and they are essentially national. Action is needed at national and at transnational level to improve the access to finance for innovation.

(vi) **The Diffusion of Technology**

As well as opening up new frontiers through research and development, Europe needs to exploit more rapidly the technologies that are already coming on the market or are about to do so. Here Japan in particular has a head-start. Some Member States (in particular Denmark) have made considerable efforts to promote a wide diffusion of technology. Others less so. Community-level action has a helpful role to play (notably the SPRINT program). But more could be done to spread information about available technologies and the results of research and development.

(vii) **Policy Coordination and (viii) Cohesion**

Particular efforts are needed to improve the coordination of science and technology policies in Europe. At the same time steps must be taken to improve the RTD fabric in the less-favored regions so as to enable them to achieve a level of excellence comparable to that of the more developed. This cannot be done without the provision of infrastructure and trained personnel. Regional and social policy instruments could be appropriately used to this end.

(ix) **Cooperation with Third Countries**

Science and technology are increasingly international commodities and further internationalization is inevitable. The issue is how best to organize cooperation in such a way that it can be a "positive-sum" game in which everybody benefits. The approaches must depend on the situation of individual countries or regions.

The European Community has a particular interest in close science and technology links with other **EFTA** [European Free Trade Association] countries where good relations are already established through COSTS, bilateral agreements as well as EUREKA.

There is scope for improved cooperation with the **United States.** It would also be appropriate to take advantage **Japanese** openings to examine the scope for mutually beneficial cooperative ventures, especially those involving expensive, long lead-time research.

As far as **developing countries** are concerned Europe has a role to play in tackling the specific problems of medicine, agriculture, energy and the environment which they face. The wider consequences for the LDCs

of scientific advances in materials and biotechnology are also of significance and will need consideration in Europe as well as at an international level.

Further reflection is needed on the potential scope for RTD cooperation with the Soviet Union and Eastern Europe, given the new developments in relations across the European continent; and also on the appropriate form for scientific cooperation with the NICs.

(x) Avoiding technological protectionism

The longer-term benefits of RTD cooperation at an international level can only be fully realized if the transfer of knowledge and technology is facilitated. But the "industrialization" of research and the growing importance of science to trade flows has increased the pressure to restrict flows of information in order to preserve competitive edge. Policy developments in the United States in this respect will need to be carefully monitored.

Main Report: Introduction

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[Text]

The Background and Objectives

1. In its most recent report on the technological challenge facing Europe[1], the European Parliament invited the Commission to give an account of the European situation in the various fields of science and technology as a basis for considering future policy requirements.

2. The importance attached by the Parliament to this issue reflects a widespread recognition of the vital role which science and technology must play in the future of Europe's economy and in the construction of a prosperous and successful European Community. That recognition is enshrined in the Single European Act itself.

3. During the past few years real progress has been made in tackling the constraints on European success. European governments have launched, both inside and outside the framework of the Community, new initiatives to foster transnational cooperation among researchers in universities, industry and the public sector itself. At the Community level there has been a new emphasis on research and development oriented towards improving industrial competitiveness (ESPRIT, BRITE in particular) as well as the quality of life. The current Framework Program 1987-1991 provides for particular efforts in these areas. Alongside the Community efforts, EUREKA has provided further evidence of the interest in and benefits from transnational cooperation in Europe.

4. Against that background the aims of this first preliminary report are:

- To draw up a **balance-sheet of progress** so far in improving Europe's position in science and technology;
- To consider the main **research needs and opportunities** which require particular attention in the context of reducing Europe's technological dependence and improving economic competitiveness and the quality of life;
- And to identify the main **science policy** issues facing Europe over the coming years.

The report is not limited to a review of Community activities in the fields concerned or to the planning horizon of the current Framework Program (1987-1991); nor does it make specific proposals for Community action. The aim is rather to provide the factual basis on which to consider what needs to be done in Europe, without at this stage attempting to identify what should be done at national, what is more appropriate for action in a transnational framework or what specifically might most effectively be done at Community level.

5. The report highlights the importance for the future of adequate efforts in basic research alongside and in support of the application of scientific knowledge and technical know-how to the solution of the main economic and societal questions facing Europe. It also addresses questions upstream of research (education) and downstream (innovation and technology transfer). It pays particular attention to the opportunities and needs arising from the completion of the Community's Internal Market in 1992.

6. The Commission intends to update this first and preliminary report during the course of 1989 in the light of the reactions to it from the Parliament, from national policy-makers and from the wider scientific, industrial and educational community. Thereafter it will publish similar factual analyses at two-yearly intervals.

The Structure

7. The report has five chapters:

Chapter I recalls briefly the central role played by science and technology in economic and social development, and some of the central issues affecting the links between basic research, applied research, innovation and competitiveness.

Chapter II summarizes recent policies and developments outside Europe, concentrating on the United States and Japan, but also examining briefly the situation and prospects in the Soviet Union as well as the emergence of new science and technology powers.

Chapter III surveys actions taken, nationally and transnationally, in Europe to mobilize its resources in the field of research and technological development (RTD).

Chapter IV considers the main requirements for research to improve Europe's **competitive position,** notably in the context of the completion of the Internal Market; to respond to the needs of society through improvements in the **quality of life;** and to increase Europe's capacity to pursue its own scientific and technological options where necessary, by **reducing its dependence on others.**

Chapter V outlines the main issues for science policy in Europe during the coming years.

The Inputs

8. The analysis in the report reflects a multiplicity of inputs. It draws heavily on the advice of the special groups established to advise the Commission on R&D trends, needs and priorities (CODEST [Committee for European Development in Science and Technology], CREST, IRDAC, and the Advisory Committees on the coordination of individual research projects and programs); the independent evaluation panels on Community programs; systematic monitoring of scientific and technical literature and professional meetings; the views of researchers and research users in industry and universities, as well as consultants; science and technology administrations in Member States; the advice of the Commission departments concerned, both the "customers" for the "producers" of research; as well as the European Parliament itself. It also takes fully into account the work in similar fields undertaken by other international organizations, such as the OECD.

Except where otherwise stated, the figures given are averages for the European Community. In some cases data for Spain and Portugal are not yet available; while data for Luxembourg are limited. There are often wide variations around the average (see Chapter III).

Some gaps in data available from the Member States have placed limitations on the depth of the analysis in Chapter III of national trends. These limitations should be remedied in future reports in the light of the ongoing discussions and analysis of national policies within the framework of CREST. As stated later, the Commission intends to concentrate in more detail on trends and policies in the Member States in future reports on science and technology in Europe.

I. Science, Technology, and Europe's Economic, Social Needs

(i) Science, Technology, Economy

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 7-10

[Text]

Economic Trends

1.1. In its analysis[2] of the economic benefits of completing the Community's internal market the European Commission underlined the importance to economic growth and competitiveness of economic sectors incorporating the results of advanced technologies, and drew attention to the weakness of the Community's performance in these fields.

1.2. For these "high technology" sectors (electrical and electronic goods; office and data-processing mechanisms; chemical and pharmaceutical goods) world demand has been growing at around twice the rate of that for manufactured products as a whole. Yet these sectors account (1985) for only 22.4 percent of the value-added of the whole of Community industry, as against nearly 29 percent in the United States and more than 28 percent in Japan. Moreover, the share has been growing more slowly in the Community than in either of its major competitors: between 1979 and 1985 it grew by 32 percent a year in the Community, compared with 3.7 percent in the United States and 17.1 percent in Japan. The differences between Europe and Japan are particularly striking in the case of electrical and electronic goods, where Japanese domestic demand grew by nearly 21 percent, and European demand by 3.5 percent.

1.3 In terms of exports the Community has also been losing ground in the case of electronics and electrical equipment, in cars and other forms of transport, office machinery, and information technology. The only high growth sectors where the Community has maintained a favorable position on export markets are chemicals and pharmaceuticals. Japan in particular has continued to push ahead in the export of high-technology products. Between 1979 and 1985 Japan increased its world market share by nearly 12 percent for electrical and electronic equipment, by over 9 percent for cars and by 5.5 percent in information technology and office automation[3].

1.4. At the same time the Community has been increasing its **dependence** on imports of such products. Imports from outside the Community have been growing more quickly than intra-Community trade in office machinery and information technology, electrical and electronic equipment, machinery and transport equipment. Again, only the chemical and pharmaceutical industries among the high growth sectors perform well. This increase in trade dependence reflects an underlying technological dependence in certain sectors: in the case of information technology, for example, European dependence on components has been increasing despite the improvements in the performance of the IT industry as a whole.

Table 1.2. Extra-EC Imports and Exports by Branch, Evolution Since 1980

Index 1980-100)	1982	1985	1987	1987 value (Billion ECUs)
Processed foodstuffs				
Imports	119	155	127	12.9
Exports	136	183	159	13.2
Intra-EC trade	131	185	209	22.3
Chemicals				
Imports	126	203	185	19.7
Exports	118	187	160	32.0
Intra-EC trade	128	197	206	44.9
Plastics				
Imports	118	186	184	8.3
Exports	115	178	157	14.1
Intra-EC trade	120	186	219	29.6
Leather				
Imports	99	146	150	5.9
Exports	119	211	216	3.9
Intra-EC trade	144	210	234	5.2
Paper and board				
Imports	123	175	180	14.6
Exports	125	220	216	7.2
Intra-EC trade	125	185	234	15.1
Textiles				
Imports	113	165	165	25.8
Exports	124	204	186	19.3
Intra-EC trade	120	170	201	35.9
Footwear				
Imports	116	181	173	2.8
Exports	143	271	216	3.6
Intra-EC trade	119	151	2301	5.6
Glass, ceramics				
Imports	112	162	145	2.3
Exports	122	186	164	6.5
Intra-EC trade	108	143	183	9.3
Machinery				
Imports	135	226	236	60.5
Exports	128	171	155	85.8
Intra-EC trade	119	189	232	91.1
Transport equipment				
Imports	129	202	190	19.5
Exports	139	181	159	43.8
Intra-EC trade	135	172	239	64.9
Audio/video/photo equipment				
Imports	141	215	232	18.2
Exports	139	222	207	14.6
Intra-EC trade	124	202	252	16.7

Source: Eurostat (rounded figures).

1.5 While in the high growth industries Europe continues to be underrepresented, traditional manufacturing industry remains significant. The Community accounts for some 35 percent of the GDP of the EC-USA-Japan triad, but in 1986 it produced 44 percent of the cars, 42 percent of the steel and 40 percent of the textiles and clothing of the three combined. A number of the traditional sectors have improved their position during the past few years by large-scale investment in new technologies and major research efforts (Table 1.2.) Textiles and automobiles are two examples. Others, such as the paper and board processing industry or parts of the machine-tool industry, have been less successful. Even those that have improved their position through innovation and automation (especially automobiles where productivity has grown by over 30 percent 1980-87) face the prospect of increasing world competition. One successful company strategy in some industries has been to seek to capture more of the top-end of the market through the application of new technologies and their integration into the products.

1.6. Europe's interest lies in both reducing its dependence on the third countries in the high growth sectors and harnessing the new technologies to improving the competitiveness of its traditional industries.

The Characteristics of the Emerging Industries

1.7. The characteristics of the emerging industries and their contribution to overall economic growth and development have been the subject of considerable enquiry during the past few years[4]. Recent trends in these sectors in European Community are analyzed in detail in the forthcoming "Panorama of EC Industry: 1989" which will shortly be published by the Commission and to which reference is made in more detail in Chapter IV below.

One fundamental characteristic of the emerging industries is that they are heavily "science-based" or "science-related," with their products embodying to a significant degree the results of advanced research and development. Secondly, they reflect the emergence of new "generic" technologies with pervasive applications. Thirdly, they are calling on the expertise of an increasing range of scientific disciplines. Fourthly, some of the new fast growing sectors demand a much closer and more interactive relationship between fundamental research and commercial production than has hitherto been the norm. Biotechnological products and technologies have been described, for example, as "growing directly out of the laboratories." Fifthly, however, the pace of economic growth is linked to the diffusion, application and modification of new generic technologies by smaller innovating firms, alongside the major enterprises with their large R&D resources and the contribution of universities and research institutes.

Technology and Economic Growth

1.8. The importance of technology and the underlying scientific disciplines to growth, trade and welfare is certain to grow rather than to diminish over the coming years. The information technology revolution is far from over, as applications of IT permeate industry, households, transport and communications. On one estimate[5] the electronics industry, with an output value estimated at US$ 485 billion in 1985 (or 4.7 percent of Free World GNP) is likely to reach 8 percent by 2000; another expects the share of telecommunications in developed countries' GNP to grow to 7-10 percent by the early 1990s (compared with 5 percent in the United States in 1985, and 3 percent in Japan and Europe)[6]. Biotechnology is likely to impact on a large number of economic sectors within the next decade and its influence could spread rapidly thereafter, affecting the chemical and pharmaceutical industries, agriculture and food and energy. New materials could induce major savings in resources and change the basis of comparative advantage between traditional raw material producers and countries that depend on imports.

1.9. In this rapidly changing world economy, growth and competitiveness will depend increasingly on successful interaction and feedbacks between the progress of scientific knowledge ("science push"), the identification of market opportunities and needs ("market pull"), the pervasive diffusion of knowledge of, access to and modification of available technologies as well as the opening up of new technological frontiers.

1.10. The Commission's analysis of the costs of non-Europe shows that progress in removing market barriers within Europe will of itself play an important role in creating the conditions for the Community to improve its competitive position. It will encourage some integration of companies, laying the basis for pooling of R&D resources to achieve the "critical mass" required to take major new steps forward in generic technologies. It will also encourage more competition and the consequent encouragement of innovation. But, the creation of the internal market in alone will not solve the problems of competitiveness. Progress in this direction must be accompanied and encouraged by adequate public policies on R&D that take account of the new realities (the ever-closer links between science, technology and the market-place) and that create the right framework conditions in which these links and interactions can best be established.

(ii)Science, Technology and Consequences of Growth, Change

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 10-13

[Text] 1.11. Improving Europe's industrial competitiveness is not in any case the only issue to which science policy can and should make a major contribution. The pressures of technological change also have important social consequences, in terms of the pattern of employment and the distribution of wealth and economic opportunity across Europe, and consequent implications for the economic and social cohesion of the European

Community. They also raise issues of an environmental and ethical nature, as well as new questions for international relations. The challenge for science policy is to help find solutions for the problems posed by scientific and technical advances as well as to help seize the opportunities which they offer.

1.12. The effect of the new technologies on employment over the longer-term is not yet well understood. A number of studies suggest that the net effect of information technologies on employment will be relatively small[7]. And advances in biotechnology and new materials could increase, rather than reduce employment. But it is obvious that there are major structural adjustments within any economy and adverse effects for some regions and industries. Moreover, Europe has been less successful so far than the United States and Japan in translating economic growth into the growth of employment opportunities. High unemployment may itself create resistance to the diffusion of technologies that are labor-saving and, in the absence of policies to mitigate the effects, encourage a Luddite approach to new technology.

1.13. Similarly, there is a risk that technology will be seen as the cause and not the cure for environmental problems unless public policies are focussed sharply on encouraging the application of scientific knowledge and technological resources to the solution of the problems of atmospheric pollution, waste disposal and safety, and to prevention of environmental damage.

1.14. Advances in medical and biological sciences offer the prospects of major improvements in health and agriculture over the coming years. but there are important ethical issues posed by genetic engineering, and some evidence of public concern about the effects of the environment and the risks to health of certain experiments in biotechnology. A considered approach to these issues must be an integral part of European efforts to ensure an adequate S&T base.

1.15. The external aspect is also of major importance. The mastery of technology and the promotion of scientific advance in Europe have consequences not only for our competition with our major industrial trading partners about also for the trade and development of the developing countries. Biotechnology may offer us the prospect of more efficient agriculture in the longer-term, producing crops that correspond more precisely to market requirements and reducing the risks of surpluses of unwanted products. It should also help to transform Third World agriculture and medicine. The advance of new materials, on the other hand, is likely to have consequences for those developing countries that are exporters of traditional materials.

1.16. Through the Single European Act the Governments of the Community's Member States have expressed their commitment to the protection of the environment and to a more economically and socially cohesive Europe. They have also underlined the importance of the external aspects of Community policy in the field of R&D. The final chapter of this report outlines how these commitments can be reflected in and supported by science and technology policy itself.

The Changing Scientific Environment

1.17. Science policy has also to take account of the other factors, namely: the accelerating pace of scientific discoveries; the increasing cost of research; in which the traditional boundaries between sectors are breaking down and more integrated systems are developing.

Chemistry provides a vivid example. There has been an explosive growth in new compounds which are now doubling in number every 6-7 years compared with every 40 years in the 1940s. At the same time chemists are now using more and more sophisticated and costly instruments and analytical aids (laser, spectroscopic instruments, the electron microscope, synchrotron light, etc.) and calling increasingly on the help of information technology.

All this means that financial resources have to be depreciated over a shorter space of time and directed at an ever-growing number of problems. This has major implications for science policy both at national and at European level. It underlines the need for the most rational use of resources (financial, human and physical) by the avoidance of duplication and pooling, and it poses more acute problems in the definition of research priorities for public funding than in the past. It also highlights the importance for industry of having a large enough market in which to sell the products of research and thus to achieve a rapid depreciation of expenditure.

Science and Technology are vital in improving Europe's competitive position in the context of the completion of the Internal Market. They also have a major contribution to offer in meeting the societal needs of the European society for a cleaner and safer environment and better health care.

The mastery of science and technology is essential to reduce technological, and thus economic dependence and to allow Europe to be able, where it wishes to do so, to make its own technological choices.

The translation of these economic and social needs into specific requirements for research is considered, sector by sector, in Chapter IV.

But science and technology are increasingly expensive as science develops at an accelerating pace. The costs of research are placing an increasing strain on the financial capacities of individual companies or Member States. The resources devoted to science must be used to the best effect. Further pooling of these resources may offer major advantages.

II. European Science, Technology From Comparative Perspective

Trends in Our Main Competitors

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 p 15

[Text] 2.1. The performance of Europe vis—vis its major competitors can be measured in terms of **resource inputs** (financial and human) to science and technology, quantifiable scientific and technological **outputs**, and the administrative and policy framework within which science and technology develop. This chapter begins with a short analysis of the trends in inputs (how much is spent on R&D, by whom, what scientific personnel are available) and in proxy measures of output (patenting activity, technological trade balance, technological balance-of-payments). The comparison is between Europe[8], on the one hand, and the United States and Japan, on the other. The chapter then examines recent policy developments in the United States and Japan before concluding with a short survey of trends in some emerging science and technology powers.

2.2. The chapter draws heavily on available comparative data drawn up by the OECD, on more detailed data for Community Member States assembled by the Statistical Office of the European Communities, and on a comparative study of the Community, United States and Japan, prepared for CREST in the context of discussions on the coordination of national R&D policies in Europe[9].

In commenting on policy developments the chapter concentrates on **recent trends**. More details on the structure and organization of R&D in the United States and Japan can be found in the annex.

(i) Comparative Trends in Science, Technology

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 16-22

[Text]

The Level of Funding

2.3. Fully comparable data on total spending on R&D exist only for 1985. These show that in absolute terms total spending (civil and military) in the United States was 1.75 times that of the European Community and 2.9 times that of Japan:

Table 2.1. Gross Domestic Expenditure on R&D Mio ECU Current (ppp)

	EC(12)	USA	Japan
1981	48,072*	76,722	25,136
1985	76,250**	134,645	48,056

*estimates for Belgium and Portugal. Excludes Luxembourg.
**estimates for Belgium, Spain and Portugal. Excludes Luxembourg.

Source: Commission service estimates and Table 2 of OECD "Main Science and Technology Indicators," Paris 1988.

In terms of spending as a share of GDP the United States is also in the leading position:

Table 2.2. Gross Domestic Expenditure on R&D as a Percentage of GDP

	EC(12)	USA	Japan
1985	1.9	2.8	2.6

Only one Community country (Germany) has an R&D intensity[10] (2.8 percent in 1987) that is comparable to that of the United States or Japan.

The level elsewhere varies between 2.3 percent (UK and France), 2.1 percent (Netherlands) down to 1 percent or less for some smaller Community countries. The U.S. figures are, however, bolstered by the high level of spending on defense R&D. If defense expenditure is excluded, the share of U.S. GDP devoted to R&D drops to about 1.9 percent, that of the Community (where military R&D accounts for some 25 percent of the total government expenditure on R&D) falls to 1.4 percent, while that of Japan (where military R&D expenditure is prima facie negligible[11]) is almost unaffected.

2.4. In all three areas spending on R&D has grown significantly throughout the 1980s, but the growth has been more marked in the United States and Japan than the Community. Between 1981 and 1985, R&D intensity rose by an average annual rate of 1.8 percent in the Community, by 2.6 percent in the United States and by 4.1 percent in Japan. The Japanese figure is even more striking, bearing in mind that the growth of United States spending during that period and subsequently has been concentrated on defense R&D. If defense expenditure is excluded, Japanese growth in total R&D spending (public and private) is estimated to have been more than twice that of the United States and Europe (9 percent as against 4 percent)[12].

Expenditure and Execution: the Contribution of Public and Private Sectors

2.5. In terms of the relative financial contributions of public and private sectors to R&D, the Community lies

between the United States (where the public sector share is highest) and Japan. But in most Community countries there is a significantly lower level of industrial involvement in the execution of R&D programs than in either the United States or Japan.

Around one-half of U.S. spending on R&D is financed from public sources, and through the 1980s this government spending has been growing steadily, driven by sharp increases in military R&D; private sector spending has been less buoyant. But more than 70 percent of R&D has continued to be carried out by industry, given that a large share of military R&D is subcontracted to the private sector.

In Japan, on the other hand, industry both finances and carries out the bulk of R&D. Less than 30 percent of Japanese R&D is financed by the public sector, 70 percent being financed and executed by the private sector, especially industry; and in the natural sciences the figures are even further weighted towards industry. In the Community around 45 percent of spending is financed from public sources. But only Germany and Belgium have shares of R&D carried out by industry that are on a par with Japan and the United States.

R&D Personnel

2.6. The trends in the overall levels of expenditure are parallelled b} those as regards R&D personnel. The proportion of research scientists and engineers in the labor force is significantly higher in the United States and Japan than in European countries, even when allowance is made for differences in data coverage. Moreover, the proportion has been growing much more rapidly in Japan. In absolute numbers the United States has a much larger R&D workforce (825,000 in 1986) than either the Community (an estimated 500,000) or Japan (now up to 400,000). But the U.S. figure has been relatively stagnant, while that of Japan has increased steadily and sharply[13].

Table 2.3. Scientists and Engineers in R&D as a Proportion of the Total Labor Force 1965-86

	USA	Japan	Germany	France	UK
			Nos per 10,000 labor force		
1965	64.7	24.6	22.7	21.0	19.6
1970	64.1	33.4	30.8	27.3	n.a.
1975	55.3	47.9	38.6	28.4	31.1
1980	60.0	53.6	n.a.	32.4	n.a.
1984	65.1	62.4	49.1	41.2	34.2
1985	67.4	63.2	n.a.	n.a.	32.8
1986	69.0	n.a.	n.a.	n.a	n.a.

Source: National Science Foundation, International Science and Technology Update 1987

Figures include all scientists and engineers engaged in R&D on a full-time basis except Japan, where data include persons primarily employed in R&D, and UK where data include only the government and industry sectors.

The Output From R&D

a) Applied Research

2.7. Three measures can be used together to provide a proxy for the "productivity" of applied R&D, namely: patenting activity, and especially patenting in the United States as the largest single world market; the technological balance of payments (i.e. receipts and expenditures related to patents, royalties and licenses); and the balance of trade in high-technology goods.

2.8. In terms of the total numbers of patent applications and those granted domestically, Japan now ranks above the United States and Europe. In terms of those registered with foreign patent offices it ranks third after the United States and Germany, and the number of foreign registered patents has been increasing steadily. In terms of the granting of patents in the United States, the Japanese share has doubled since the mid-1970s, and Germany alone among the larger European countries has maintained its position:

Table 2.4. U.S. Patents Granted to Inventors in Various Countries, 1975 and 1985

	1975	1985
Total	100.0	100.0
USA	64.9	53.8
Japan	8.8	18.6
Germany	8.4	9.6
France	3.3	3.3
UK	4.2	3.4
Other	10.4	11.2

Source: Derived from Appendix Table 6-11 of Science and Engineering Indicators, 1987, National Science Board, Washington DC.

The growing importance of Japan is underlined, moreover, by the number of citations of Japanese patentts

registered in the United States, which provide an indication of the quality of applied research output[14].

2.9. The picture emerging from analysis of technological balance-of-payments data is less clear cut; but the trend has been towards a reduction in the negative Japanese balance. In 1985 Japanese sales of licenses, patents etc. were equivalent to about four-fifths of her expenditure in the field[15], and more recent data suggest that the gap has closed about to zero. The figures on trade in high-technology goods, as indicated in the previous chapter, underline this growing technological strength:

Table 2.5. Export/Import Ratios in Selected High-Technology Goods, 1981-1986

	1981					1986				
	Japan	USA	FRG	Fr	UK	Japan	USA	FRG	Fr	UK
Office Mach. & Computers	2.75	3.23	0.93	0.73	0.68	6.63	1.11	0.92	0.7	0.79
Comm. Equip & Electronic Components	6.59	0.70	1.13	1.14	0.96	8.95	0.61	1.14	1.22	0.82
Scientific Instruments	6.59	0.97	1.42	0.76	1.01	6.75	0.61	1.49	0.78	0.88
Drugs	0.28	2.27	1.77	1.99	2.61	0.30	1.42	1.71	1.90	2.21
Electrical Transmission Equipment	4.32	2.3	2.07	1.49	1.44	4.56	0.97	2.00	1.21	1.23
Aircraft & Parts	0.08	3.76	0.78	1.19	1.56	0.09	2.48	0.78	1.56	1.91

Source: OECD "Main Science and Technology Indicators 1981-87," Paris 1988

In all sectors the Japanese ratio has been growing while the U.S. trade position has been weakening.

(b) Basic Research

2.10. Proxies for the output of basic research include, notably, Nobel Prizes (for natural sciences and economics) and numbers of publications of scientific papers. Here Europe is in a much stronger position, and that of Japan much weaker but already improving significantly.

Between 1946 and 1987 U.S. scientists won 196 Nobel Prizes and European ones (EC-12 and EFTA) 105, while Japan had 5.

Compared with aggregate expenditure on R&D the shares of the United States and W. Europe in scientific publications are somewhat larger, and that of Japan somewhat lower. The difference is even more marked in the share of total citations. But more significant is the increasing share of Japan and the declining share of the United States, while W. Europe's share of papers and citations has held relatively steady, with the decline of the UK share being compensated by the growth of those of France, Germany and other countries:

Table 2.6. Distribution of Published Scientific Work

	1973	1982
Japan	7.1	10.1
USA	54.4	51.1
W.Europe	38.5	38.8
Total	100.0	100.0

Source: Patel and Pavitt, Research Policy No 16 (1987), Table 18

W. Europe here comprises Belgium Denmark, France, Germany, Finland, Italy, Netherlands, Sweden, Switzerland, UK.

(ii) Trends in United States

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 23-28

[Text] 2.11. In 1986, the U.S. balance-of-trade in high technology goods became negative for the first time, reinforcing a growing concern about the ability of U.S. manufacturers to compete on world markets, the dependence of the U.S. economy on overseas suppliers of key technologies and, specifically, the increasingly dominant role played by Japan. The apparent discrepancy between increasing expenditure of R&D and weaknesses in industrial performance has prompted questioning inside and outside Congress about the spin-off from defense expenditure, about the organization of R&D spending, and has led to new R&D policy initiatives both domestically and internationally.

The Federal Budget—Defense and Civil Expenditure

2.12. Between FY 1980 and FY 1988 federal spending on R&D grew by an estimated 26 percent in constant dollar terms[16]. But defense R&D expenditure grew by 83 percent in real terms while civilian R&D expenditure fell by 24 percent. As a result of these divergent budget trends, in FY 1988 defense accounted for about 67 percent of the federal R&D effort, compared with 46 percent in FY 1980.

2.13. Equally striking is that the fastest growing element of defense R&D has been **development.** Between 1980 and 1988 defense development doubled in real terms. During the same period Department of Defense funding of basic research spending actually fell in real terms[17].

2.14. For **non-defense** spending the picture is quite the opposite. A striking feature of the pattern of recent

Federal spending is that, while spending on civil research has fallen overall, spending on basic research has actually increased by some 40 percent, notably in the physical sciences, mathematics and engineering:

Table 2.7. U.S. Defense and Non-Defense R&D by Character of Work

	FY 1980 Actual	FY 1988 Estimated	Percent Change Current $	Percent Change Constant $
	(budget authority in billions)			
Defense R&D	15.0	40.3	169	83
Basic Research	0.6	0.9	64	11
Applied Research	1.9	2.6	38	-7
Development	12.5	36.7	197	99
Non Defense R&D	16.7	18.8	13	-24
Basic Research	4.2	8.6	107	40
Applied Research	5.0	6.5	29	-13
Development	7.5	3.7	-50	-66

Source: Table 3 of Research and Development FY 1989, AAAS Report XIII, American Association for the Advancement of Science, Washington DC 1988.

With the 1989 budget under pressure the Administration continued to press for an increase in basic research of $600 millions.

2.15. The breakdown of Federal spending by category is given in Table 2.8. This demonstrates a flattening of expenditure in the energy field, rising expenditure on health research and increasing expenditure on general science:

Table 2.8. U.S. Federal R&D Expenditure 1972-1988 by Area—Constant 1982 dollars

	FY 1972	FY 1986	FY 1988
Defense	22.2	33.1	34.0
Non-Defense	17.6	14.6	16.1
Space	6.0	2.0	2.0
Health	4.4	5.1	6.0
Energy	1.3	2.1	1.9
General Science	1.6	1.8	1.9
All Other	4.2	4.0	4.2
Total	39.8	47.7	50.1

Source: Table 1-4 of source to Table 2.7.

The Spin-Off From Military R&D

2.16. It is difficult to analyze with precision the industrial spin-off from military R&D. There have undoubtedly been important spin-offs in the fields of materials, aircraft engineering, vehicle technology, computer technology and systems engineering from defense expenditure in general and from SDI in particular. Moreover, the fact that 45 percent of the work funded by the Federal budget for R&D has continued to be carried out by industry has meant close industrial involvement in Federal research efforts and the continuing availability of ready markets for the products of industrial R&D. But the more defense research has been tailored to the needs of specific military defense requirements in terms of weapons systems, communications equipment and so on, the more doubts have been expressed inside the United States about the broader industrial benefits. The Administration has responded with a number of measures to increase the potential benefits to industry and competitiveness from federally-funded research, industry military R&D. These include notably, the Federal Technology Transfer Act of 1986 and the "Competitiveness Initiative" of 27 January 1987, which provide a new framework for encouraging cooperation among Federal laboratories and between them and universities and industry.

The European situation with respect to spin-off and dual-use technologies is considered separately in Chapter III.

Industrial R&D

2.17. Table 2.9. gives an estimate of the breakdown of industrial R&D spending by area. Computers are the largest single area, followed closely by the automotive industry, then pharmaceuticals, chemicals and aerospace.

Table 2.9. Industry Spending for R&D by Business Week Groupings, 1986 (in millions)

Industry	1986	% Change from 1985
Aerospace	$3,583.9	21
Appliances	128.2	13
Automotive		
—cars, trucks	7,401.7	15
—parts, equipment	341.0	12
Building Materials	223.0	8
Chemicals	3,662.2	6
Conglomerates	1,354.2	12
Containers	19.4	3
Drugs	4,721.0	17
Electrical	1,864.0	16
Electronics	2,586.3	5
Food and Beverage	610.7	12
Fuel	1,958.4	-11
Information Processing		
—computers	7,856.5	16
—office equipment	249.2	1
—peripherals	1,615.2	9
—software, services	468.0	17
Instruments: measuring devices, controls	1,092.5	2
Leisure Time Industries	1,467.4	10
Machinery		
—farm construction	681.7	-7
—machine tools, industrial and mining	487.2	10
Metals and Mining	203.9	15

Table 2.9. Industry Spending for R&D by Business Week Groupings, 1986 (in millions)

Industry	1986	% Change from 1985
Miscellaneous Manufacturing	1,692.7	11
Oil Service and Supply	699.5	-4
Paper	349.4	1
Personal and Home Care Products	749.3	17
Semiconductors	1,309.6	10
Steel	113.0	-11
Telecommunications	2,762.0	1
Textiles, Apparels	68.0	-8
Tire, Rubber	549.8	6
Tobacco	22.5	4
Total	$50,936.4	10

Source: Based on "R&D Scoreboard, 1986" (BUSINESS WEEK, 22 June 1987).

Note: Based on SEC data for companies reporting 1986 sales of $35 million or more, and R&D expenses amounting to at least $1.0 million or 1.0 percent of sales.

Promoting Industrial Cooperation

2.18. The Administration has also taken new steps to encourage inter-firm cooperation. The first efforts in this direction were taken under the Carter Administration through a limited relaxation of anti-trust regulations. Then in 1984 the National Cooperative Research Act legalized the creation of cooperative associations for the purpose of precompetitive research. As a result a number of industrial R&D consortia have been established to pool resources in order to lay the foundations for regaining U.S. competitiveness. Those most hotly-debated is SEMATECH, a Texas-based consortium in the micro-electronics field which is receiving Federal budget support (Department of Defense) in an effort to improve semi-conductor manufacturing technology, and to recapture part of the market lost in Japan.

2.19. The framework for greater efforts in R&D by industry also includes the long-standing Small Business Innovation Research Program which is intended to encourage R&D in small high-technology business and to increase their involvement in federal R&D programs. Under the Small Business Development Act of 1982 all federal agencies with an extra-mural R&D budget in excess of $100 million are required to assign up to 1.25 percent of their budget to this goal. In 1987 the total amount of research by the companies aided under this scheme is estimated at $2 billion.

2.20. It is too early to judge the success of the various initiatives to promote cooperation within the United States. One of the results of the philosophy underlying the Competitiveness Initiative, which is the subject of major controversy, seems likely to be reduced scientific openness as a result of such measures as the granting of **exclusive licenses** by Federal laboratories to contracting companies, and more selective admittance by third country participants, reflecting concern about the potentially negative effects of "leakage" as a result of the openness of the U.S. research community and society more generally.

International Cooperation in R&D

2.21. Such concern also has also led to a new approach to international collaboration in science and technology. The growing costs of R&D and the severe budgetary pressures within the United States have militated in favor of international collaboration, opening up the prospect of foreign participation in "mega-projects" such as the superconducting supercollider, some elements in space research, an international approach to the sequencing of the human genome and so on. But concern about "leakage" has also led to an emphasis in the U.S. approach to international cooperation on the principle of "symmetrical access" to programs, facilities, results and, ultimately, markets, as well as on the need for stronger measures to protect intellectual property rights. This new emphasis is reflected in the recent agreement on cooperation in R&D between the United States and Japan.

The Prospect of Growing Skill Shortages

2.22. A further concern in the United States is about the longer-term "output" of scientists and engineers. As noted earlier, there has been no growth in the share of R&D personnel in the labor force for a number of years. This seems likely to continue. With a decreasing number of college-age students in the United States and a declining percentage of high school graduates choosing to study science and engineering one estimate[18] suggests a shortfall of more than 500,000 scientists and engineers by 2010. Meeting this potential shortfall is seen to require action to encourage more women and minorities to train in science and engineering, on the one hand; and further encouragement of foreign students to study and to stay in the United States[19], on the other. At the post-doctoral level, moreover, there will be increasing pressures to "poach" skilled R&D personnel from abroad.

(iii) Developments in Japan

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 29-31

[Text]

The Organization of Resources

2.23. In the space of 30 years (1955-1985) the Japanese share in the total R&D expenditure of the six largest industrial countries rose from an estimated 1 percent to 16 percent, placing it second only to the United States[20]; and the number of researchers has become the second largest in the free world. As noted earlier, the bulk of this effort has been in the civil R&D field, although Japanese

methods of calculating military R&D expenditure may underestimate the military effort relative to that of European countries. Certainly the Japanese have spent far from negligible amounts on R&D oriented towards naval and airforce purposes.

2.24. The private sector has accounted for by far the largest share of the increase in expenditure, notably in the field of natural sciences. Thus in 1986 the public sector accounted for only 17.6 percent of total R&D spending on natural sciences and for about 25 percent of the R&D personnel. The private sector, correspondingly, provided 82.4 percent of the funding and three-quarters of the staff, with industry accounting for close to 90 percent of the private sector effort[21].

2.25. This private sector effort has taken place, however, within the framework of a tradition of long-term and "consensus" planning and linkages between industry, Government Ministries and agencies, notably MITI [Ministry of International Trade and Industry], which has played a crucial role in coordinating actions between industry, universities and other government agencies and in helping to define long-term technology priorities. Strategies covering 10-20 year periods are common both in industry and government, and Japanese companies and government agencies have developed a complex network of "outlooks" on developments in RD. Industry has also benefitted from a range of measures to encourage the allocation of resources to R&D (tax incentives, subsidies and conditional loans) and from concerted efforts to ensure the dissemination of R&D results (each of the main Japanese Ministries responsible for research appropriations—MONBUSHO, the Ministry of Education, the SCIENCE AND TECHNOLOGY AGENCY and MITI itself—has an agency of its own concerned with dissemination and application of R&D results).

Applied Versus Basic Research

2.26. Historically, the bulk of the Japanese R&D effort has been concentrated on applied research and, even more, on development, supporting an industrial policy based on the absorption and transformation of foreign technology. From the middle of the 1960s particular efforts were made (notably through the Large-Scale Project Program) to bring together researchers from private industry and those in universities to give Japan a leading edge in applied technologies that were seen as of strategic importance (notably information technology). To a certain extent, as will be argued below, this emphasis has not changed. But technology adoption is still the main objective of Japanese Science and technology policy. Still today expenditure on applied research and development dwarfs that on basic research. According to the 1987 Survey of Science and Technology Research in Japan[22] 62.3 percent of total R&D spending in 1986 was oriented towards development work, 24.4 percent to applied research and institutions account for the major share of this basic research and industry for the bulk of the development work. But the importance of industrial basic research has been growing: in 1986 commercial organizations funded one-third of total basic research expenditure in the natural sciences. Much of this is application oriented.

Table 2.10. Breakdown of Research Expenditure in the Natural Sciences by Sector & Type FY 1986 (percent)

	Total	Basic Research	Applied Research	Development
Total	100	13.3	24.4	62.3
Commercial Institutes	100	6.1	21.6	72.3
National Research Institutions	100	13.8	27.4	58.8
Academic Institutions	100	54.2	37.4	8.4

Source: as footnote 22

These figures probably understate the trends. There is much more qualitative evidence of a new preoccupation in industry and government with Japan's basic research capacity as a key factor conditioning economic and social progress in the longer-term.

2.27. This preoccupation has been outlined most vividly in the 1987 and 1988 White Papers on Science and Technology from the Japanese Science and Technology Administration. These reports demonstrate the progress already made by Japan in establishing its scientific credentials through the contribution of Japanese scientists to major scientific journals, but underline also the weakness of basic research relative to industrial technology. These shortcomings derive in part from the limited experience of fundamental research on the part of most university-trained engineers and scientists since the brightest are often snapped up by industry before completing research degrees. The 1988 paper[23] argues explicitly that Japanese research on basic science and technology, though some of it is of high quality, is insufficient compared with research on application and development. This, it is argued, reflects in part a low level of funding by public authorities. It draws attention also to the less than satisfactory level of researchers with masters or doctoral degrees; the fact that there are fewer science graduates than engineers; and there is a lack of large-scale research facilities and data-bases.

International Cooperation

2.28. A growing recognition of the importance for the longer-term of more fundamental research, of the increasing interactions between basic research, technology development and industrial competitiveness, and of the current Japanese shortcomings in this area have led to a new emphasis on international cooperation.

Measures have been taken to facilitate the participation of foreign research workers in Japanese programs. The launching of The Human Frontier Science Program, which is intended to be a new international framework for increased cooperation on basic research in the field of biological sciences, is part of the same drive to help

remedy perceived shortcomings in scientific capacity and at the same time to respond to criticisms of the closed nature of the Japanese scientific and technological system. One important issue for the future will be to ensure that the cooperation that ensues provides benefits to all the parties concerned.

(iv)Changing International Environment

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 32-35

[Text] 2.29. Apart from the changing preoccupations of Europe's two main competitors (industrial competitiveness in the United States, basic research in Japan), other factors could also impact significantly on the international environment in which European science and technology develop in the longer-term. Particularly important will be the future direction of the Soviet economy, on the one hand, and the longer-term results of science and technology polices in the newly-industrializing countries (NICs) and China on the other.

2.30. In the **Soviet Union** today military R&D absorbs a dominant share of scientific talent and budgetary resources. At the same time science management has been plagued by the familiar bureaucratic ills associated with the centralized command system of organization. President Gorbachev's efforts to reform and modernize the Soviet economy, if successful, will inevitably mean some reallocation of scientific resources to civil uses. As a consequence, over time the USSR could become an increasingly important force in terms of science and technology. The USSR has a solid tradition of theoretical mathematics; work is already under way on the Fifth Generation Computer; the Soviets already have considerable expertise in areas such as space, advanced materials and molecular biology. They have already by far the largest number in the world of scientists and engineers engaged in R&D as a proportion of their labor force—on some estimates 65 percent more than in the United States. Economic and administrative reforms are likely to increase the effectiveness with which these human and financial resources are deployed.

2.31. During recent years, European industry has been confronted with increased competitive pressure from the **newly industrializing countries** in Asia and Latin America. This competition concerns traditional industries (textiles, steel, shipbuilding, automotive industries) as well as high tech sectors (consumer electronics, IT and microelectronics, space and aeronautics). This challenge will become even more serious as the more established NICs have to face new competition from other industrializing countries (e.g. Thailand, Indonesia, Malaysia, Philippines) with labor cost advantages on the one hand, and offensive technology development strategies in the industrialized countries on the other hand.

Therefore the most dynamic NICs are now planning a substantial growth in R&D spending and a strategy for the development of highly qualified personnel who will be very much on a par, scientifically, with their counterparts in the United States but at the same time much cheaper (because salaries will be lower).

2.32. This is particularly clear in the case of the **Republic of Korea.** Up to now **Korea's** competitive advantage in, notably, the electronics industry has been established on the basis of the successful import and adaption of existing technologies, combined with cheap labor. Its indigenous scientific and research capacity, on the other hand, is limited. But efforts are now under way to improve the available indigenous resources, notably through an expansion of graduate school education in the scientific fields, joint efforts among existing R&D institutes, universities and industry in relation to selective large-scale R&D projects and some attempts to lay the foundations for a basic research capacity. Public R&D spending is expected to grow from 2 percent of GNP to more than 3 percent by 1991; and the number of researchers will grow from 13/14 per 10,000 of the labor force in 1987 to a planned 30 in 2000. This reflects a growing perception that as technology becomes more sophisticated an increasing scientific and technical capacity is required to master, exploit and adapt it. Growing wage costs and currency appreciation have also played a role in underlining the need for improved indigenous scientific capacity.

2.33. Other industrializing countries in Asia and Latin America too have clearly recognized the importance for the longer-term of a solid indigenous scientific base and research capacity. Since 1984, a strong industrial restructuring effort has been undertaken in **Taiwan,** aiming at giving priority to high tech sectors, notably telecommunications, integrated IT systems and biotechnology. With a US$ 633 million civil R&D budget in 1986, and more than 1 percent of GNP allocated to R&D, Taiwan is close to Korean standards, including a high proportion (14 per 10,000) of researchers in its population.

With the help of the World Bank, **Brazil** launched its ambitious Program for Support in the Development of Science and Technology (PADCT) in 1982 which was further extended in 1986. R&D funds, which reach nearly 1 percent of the GNP, are supporting projects in areas vital to economic development: biotechnology, chemistry and chemical engineering and geosciences.

With 0.6 percent of GNP devoted to R&D and a considerable scientific and technological potential, **India** is emerging as a nuclear energy, space and informatics international actor.

Other developing countries which have clearly recognized the importance for the longer-term of a solid indigenous scientific base and research capacity include **Israel, Hongkong, Singapore,** and **Argentina.**

2.34. In **China** the improvement of scientific and technological capacity is seen as fundamental to the achievement of ambitious longer-term goals of economic growth and development. Major research programs have been launched, aimed at catching up in the mastery of technology in seven main fields—biotechnology, aerospace, information technology, lasers, robotics, energy and advanced materials. Other programs are aimed at increasing the technological inputs to the export industries and the level of scientific and technical education more generally. Already China is attempting to enter the international satellite launching market.

2.35. The longer-term consequences of these trends for the advance of scientific knowledge and for the pattern of world economic growth and trade are clearly impossible to predict. But the increasing importance attached to science and technology in all these countries and the potential for the emergence of significant new science and technology powers are factors which European countries cannot ignore in their own approach to science and technology policies at a national, European and international level.

Europe as a whole is spending less on R&D than its major competitors; and European industry much less. Moreover, the share of research scientists and engineers in the labor force is significantly higher in the United States and Japan.

Despite its own problems of industrial competitiveness the United States continues to benefit from major advantages in the field of R&D (market size, levels of military R&D expenditure) and renewed efforts are being made to maximize the industrial spin-off from Federally-funded programs (including, notably, military R&D) as well as to improve interfirm cooperation. There is also an increasing trend towards tighter restrictions on the flow of scientific and technical knowledge out of the United States.

Japan for its part is now extending its expertise into the field of basic research to complement its strong position in applied research and technological development. This reflects not only a wish for greater integration into the international scientific community, but also the recognition that a capacity in basic research will be essential in order to influence the direction of technological development in the future.

Other industrializing countries are also beginning to develop an indigenous S/T capacity. Europe faces major challenges from this changing international environment.

III. Mobilizing Europe's Resources

(i) At National Level

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 37-46

[Text] 3.1. A growing recognition of the challenges facing Europe has already led to some considerable rethinking of national science and technology policies during the 1980s. This has been characterized by redefinitions of public sector expenditure priorities, both as between RTD and other public policies and within RTD budgets themselves; a more important industrial orientation in most countries; a new focus on measures to improve cooperation between industry and universities; a concern about the pattern of higher education and training at one end and about the pace of innovation at the other; and the search for better value for money through improvement in the mechanisms for evaluating choices between funding priorities and the success of programs. This process of reevaluation is still going on: in the United Kingdom a major review of science policy has been under way; in Italy and Spain there have been important reorganizations of the administrative apparatus for dealing with science policy; Germany has witnessed recent changes in the pattern of Federal spending with a greater priority now to be given to space research.

The Resources Applied to R&D

3.2. The picture varies considerably among Community Member States in the share of national resources devoted to R&D; in the relative importance of the public and private sectors; and in the sectors to which resources are applied.

3.3. In terms of the R&D effort the total volume of spending is dominated by three countries: Germany, the United Kingdom and France which together account for over three-quarters of total public and private spending on research and development in the European Community. Indeed it is characteristic of U.S. and Japanese observers to compare the performance of their own countries with these three countries, and especially with Germany which accounts for around 30 percent of the total.

3.4. All three countries, together with the Netherlands, have higher than Community average shares of GDP allocated to R&D. Once again the German position stands out from the others, with some 2.8 percent (1987). Both France and Germany have been most successful in increasing total expenditure, with increases in the R&D intensity of their economies of 18 percent and 26 percent respectively between 1975 and 1985.

3.5. At the other end of the spectrum lie Spain, Portugal and Greece, with shares of R&D in GDP of respectively 0.7 percent, 0.4 percent and 0.35 percent. In all of these countries public policy has emphasized the need for increasing expenditure, but this appears so far to have achieved significant results only in Spain. where even in the mid-1980s the intensity of the R&D efforts was below 0.5 percent.

3.6. The remaining Community countries lie between these two extremes. Here Italy's performance is the most striking, with rapid growth in resources devoted to R&D throughout the 1980s. In real terms total (public and private) expenditure on R&D grew by well over 10

percent per year, pushing up the share of R&D in GNP to around 1.5 percent in 1986. There is a policy objective to double this figure by the early 1990s.

Table 3.1. The Intensity of R&D Spending by Member States: R&D as a Percentage of GDP (1987 or Nearest Year)

	1981	1987
Germany	2.45	2.8
France	2.0	2.35
UK	2.4	2.3*
Netherlands	2.0	2.3
Belgium	n.a.	1.5*
Denmark	1.1	1.3*
Italy	1.00	1.5+
Ireland	0.7	0.8
Spain	0.4	0.7
Portugal	0.35	0.4**
Greece	0.2	0.35+

Source: OECD and national data. Figures for Luxembourg not available.
* 1985
** 1985
+ 1986

3.7. The significant differences among Member States are also evident in terms of numbers of research personnel. Table 3.2. shows that Germany and France together account for well over half of the entire Community R&D personnel, with Germany alone providing some 35 percent.

Table 3.2. R&D Personnel (1985)

	Nos. (1000)	Percent of Community total (EUR=100)	Nos. per 1000 employed (1983)
Germany	398.0	35.0	4.8
France	270.0	24.0	3.9
UK	174.0*	15.0	–
Italy	118.0	10.5	2.7
Netherlands	61.5	5.5	3.7
Spain	32.0	3.0	1.0
Belgium	32.0**	3.0	2.6
Denmark	20.0	2.0	2.7
Portugal	9.0***	1.0	0.7
Greece	6.0**	0.5	0.6
Ireland	6.0***	0.5	2.8(1984)

Source: OECD and national data.
* 1986
** 1983
*** 1984

3.8. In terms of the relative importance of the public and private sectors as sources of funding for R&D and as "performers," the position also varies considerably. In all Community countries the public sector remains a crucially important source of funds. In only Germany and Belgium is public spending on R&D less than business expenditure. The increase in German expenditure on R&D, moreover, has been due more to growing business expenditure than to public expenditure, and the private sector has accounted as a result for a growing share of the total R&D funding. In Germany too a larger share of publicly-funded research than in other Community Member States is carried out by the private sector. In Italy and France, on the other hand, the improvement in R&D intensity has been the result, principally, of increased government expenditure.

Table 3.3. Financing and Execution of R&D in the Community, 1985

	Financing Shares in %		Execution Shares in %		
	Business	Public Sector	Business	Public Sector	Other (Univers. etc.)
Belgium	(66)*	(34)*	(69)*		—(31)*—
Denmark	49	46	55	21	24
Germany	61	38	72	12	16
Greece	26	74	n.a.	n.a.	n.a.
Spain	49*	50*	(40)**		—(60)**—
France	41	53	59	25	16
Ireland	45	47	51		—49—
Italy	45	52	57		—43—
Netherlands					
50	45	55	19	26	
Portugal	n.a.	62	n.a.	n.a.	n.a.
UK	46	43	63	20	17

Source: OECD and National data—Figures for Luxembourg not available.
* 1983
** Estimates for 1987

3.9. Table 3.4. illustrates in summary from the differences between Member States in their levels of R&D intensity (both total and industry-intensity) and also in levels of employment in "technology-based" industries. The outstanding position of Germany contrasts with that of the less-developed members of the Community:

Table 3.4. Indicators of RTD—EC(12)=100

	A R&D Intensity (total)	B Business R&D Intensity	C "High Tech" Employment	D Composite Index
Germany	134	138	118.5	131
France	113	111	95	108
UK	120	83	103	106
Netherlands	107	102	95	103
Belgium	72	72	90	76
Denmark	60	80	70	68
Italy	59	46	80	61
Ireland	41	49	82	53
Spain	23	7.5	n.a.	18
Portugal	18	17	n.a.	n.a.
Greece	11	5	n.a.	n.a.

Source: Derived from STRIDE report, National Board for Science and Technology, Dublin, November 1987
R&D Intensity = Total expenditure on R&D/GDP.
Business R&D Intensity = Business expenditure on R&D/Gross Value-Added.
High-Tech employment = employment in chemicals, man-made fibers, office machinery and data-process machinery, processing of rubber and plastics, nuclear fuels—aggregated and expressed as a ratio to total employment in all industries.
The composite index at D is a weighted average of A, B and C.
Data are for 1983 and 1984, except for Portugal (1982).

Regional Differences in RTD Capacity

3.10. Such differences in R&D resources and their use are even more striking if measured at the regional level. In 1987 the European Commission invited a group of external experts to analyze the situation at regional level. Their extensive report[24] highlighted regional disparities in R&D spending and in technology levels that are much greater even than those in terms of GDP per capita. Even as between the Member States themselves (Table 3.4.) there is a difference of 12:1 in the levels of R&D intensity and of 28:1 in the intensity of business investment in R&D. At the sub-national level the disparities are much greater. In terms of the intensity of business expenditure on R&D, for example Oberbayern enjoys a score three times the Community average, while in a number of regions in Italy, Spain, Greece and Portugal both business expenditure on R&D and expenditure by the higher education sector are negligible. The consequences for desirable policy approaches are discussed in Chapter V.

It should be added, that the link between R&D intensity and rates of economic growth is not a simple one, as the case of Denmark illustrates. Denmark has a lower than average level of R&D intensity. But Danish policy (cf.5.20 below) has concentrated much effort on the diffusion and adoption of technologies, with R&D resources directed to are as in which Danish industry is strong. Denmark offers an interesting model of "small country" or regional strategy.

Trends in R&D Policies and Public Funding

3.11 In the majority of Community Member States there has been a real growth during the 1980's in the government appropriations for R&D. This has been most striking in the case of some of the less developed countries (notably Greece and Spain) and in France, Italy and Denmark, each of which has increased R&D resources faster than GDP (table 3.5.). Many of these countries have increased public expenditure on R&D more quickly than public expenditure overall.

Overall expenditure in the UK, on the other hand, has held broadly stable in real terms for much of the 1980s,

with some redeployment of defense R&D expenditures to the civil sector. In Germany, as noted earlier, government appropriations have grown only modestly compared with private sector financing.

Table 3.5. General Characteristics of Budget Appropriations for RD in 1986

	Government R&D appropriations in 1986 at current values and exchange rates (million ECU)		Government R&D appropriations at 1980 prices and exchange rates—Annual average rate of change (percent)				Contribution of Member States to the EUR 12 total (percent)		Ratio of government R&D appropriations to total budget (percent)		Ratio of government R&D appropriations to gross domestic product (percent)	
			total		civil							
	total	civil	81-86	86-87(1)	81-86	86-87(1)	81	86	81	86	81	86
Belgium	653	642	1.3	-1.6	1.1	-1.2	2.4	2.6	1.31	1.33	0.63	0.57
Denmark	509	507										
6.8	19.4	8.0	19.5	1.01.4	1.36	1.55	0.49	0.63				
Germany	10049	8832	0.6	2.0	-0.1	1.9	30.3	28.1	4.06	4.20	1.15	1.10
Greece	99	97	4.8	12.2	5.4	12.7	0.3	0.3	0.51	0.67	0.16	0.25
Spain	802	764	6.4	21.3	6.4	17.3		2.3		1.61	0.28	0.34
France	10273	6935	3.3	-3.0	5.1	-7.3	27.9	29.3	5.62	6.34	1.31	1.44
Ireland	116	116	4.2	1.6	4.2	1.6	0.3	0.3	0.74	0.80	0.39	0.44
Italy	4409	4033	7.5	8.1	7.0	8.8	8.3	19,7	1.60	1.60	0.65	0.85
Netherlands	1705	1658	1.8	1.7	1.8	1.5	5.2	5.0	2.34	2.40	0.93	0.96
Portugal	92	92		35.0		35.0		0.3		1.4		0.32
United Kingdom	6787	3329	0.0	-0.4	0.5	-3.3	22.4	20.3	3.18	3.04	1.31	1.24
EUR 12	35492	27003	2.2	0.6	2.7	0.3	100.0	100.0	3.33	3.11	1.02	1.04
European Communities	661	661										

(1) Comparison of provisional budgets

Source: Government Financing of Research and Development in Community Countries, Statistical Office of the European Communities OS/12/87

3.12. As far as the distribution of public funds among different categories of expenditure is concerned there are again wide differences (Table 3.6.).

Table 3.6. Breakdown of Provisional R&D Budgets by Objectives in 1986 and 1987 (percent). Source: Government Financing of Research and Development in Community Countries, Statistical Office of the European Communities OS/12/87.

	EC/CE		EUR 12		DL		DK		DE		GR	
NABS Objectives	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
1. Exploration and exploitation of the earth	0.6	0.7	1.6	1.8	2.5	3.1	1.3	1.5	2.1	1.9	5.5	7.1
2. Infrastructure and general land-use planning	0.8	0.6	2.2	2.2	0.6	0.7	2.4	2.3	1.9	1.9	0.4	0.3
3. Control of environmental pollution	5.8	5.3	1.6	1.7	2.4	2.2	1.5	1.3	3.3	3.3	3.4	2.1
4. Protection and improvement of human health	4.1	2.8	3.5	3.6	2.1	3.0	3.3	4.8	3.0	3.2	9.3	7.4
5. Production, distribution and rational utilization of energy	56.8	51.6	8.7	1.1	10.1	9.5	6.7	4.4	10.5	8.7	2.6	3.6
6. Agricultural productivity and technology	1.9	1.5	3.6	3.6	7.2	7.6	7.0	8.5	2.0	2.0	24.9	26.0
7. Industrial productivity and technology	26.7	33.2	12.8	13.7	16.2	12.8	20.6	16.2	14.3	15.3	8.7	11.2
8. Social structures and relationships	0.8	1.1	2.2	2.1	0.7	0.5	4.3	3.6	2.3	2.3	6.47.3	
9. Exploration and exploitation of space	1.1	1.5	4.6	5.4	7.3	9.8	3.1	2.6	4.5	4.9	0.6	0.4
10. Research financed from general university funds			22.1	23.0	22.8	22.3	29.5	32.1	31.8	31.5	26.925.3	
11. Non-oriented research	1.4	1.8	11.3	10.7	20.5	23.6	19.7	22.3	11.8	12.3	6.1	6.7
12. Other research			0.8	1.1	6.3	3.8			0.1	0.1	2.2	0.2
Total Financing of Civil R&D	100.0	100.0	75.1	76.1	98.5	98.9	99.5	99.6	87.6	87.5	97.1	97.7
13. Defense	-	-	24.9	23.9	1.5	1.1	0.5	0.4	12.4	12.5	2.9	2.3
Total financing	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Even between the three largest spenders (Germany, France and the UK) there are major divergences as a consequence in the first place of **defense** expenditure, which accounts for 51 percent of total expenditure in the UK, for 34 percent in France and for 12.5 percent in Germany.

In the **civil** sector, the most important categories of expenditure are, generally research financed from general university funds and non-oriented research. The Netherlands and Belgium concentrate much of their R&D support in the universities, and Germany and Denmark also give above-average shares of total public funding for research to higher educational institutions. In the United Kingdom, on the other hand, the percentage of funds going to the universities for research purposes is well below average and that to finance non-oriented research significantly below and declining; while in France the picture is mixed, with university-funding below average but support for non-oriented research high.

Outside these categories Germany and the Netherlands spend higher-than-average shares of public funds on environmental research; Italy has focussed in the past a particular resource effort on **energy** (notably nuclear energy) research; Greece, Denmark, Ireland and Portugal on R&D to improve **agricultural productivity**. But generally the most important growth sector during the 1980s has been R&D **on industrial technologies**, where there have been major investments by Germany, France, Italy, Spain, Ireland and Denmark in particular.

3.13 This latter feature of R&D budgets is associated with the greater general **industrial orientation** in public R&D policy than hitherto. This has been characterized by:

- Measures to encourage higher levels of spending on research and development by industry itself. Practically all Member States now provide some form of tax relief for industry on R&D investment. Many offer, in addition, financial incentives in the form of grants or loans. As noted above, the Netherlands and Germany, in particular, have witnessed a steady and significant growth in industrial R&D spending;
- The targeting of financial support on specific "high" technologies with major industrial applications. Information technology has been the focus of particular attention in most countries (early examples of national policy initiatives in the 1980s included the Plan d'Action de Filire Electronique in France, the Information Stimulation Plan in the Netherlands, the Alvey Program in the UK. These are now being phased out, to a large extent superseded by transnational actions (see 3.49 below);
- Measures to promote better technology transfer—the dissemination of research findings to industry. Generally this has been concentrated on the results of civilian research efforts. But in the UK earlier this year a scheme was launched (the Civilian Industrial Access Scheme) to increase the spin-off to industry from defense R&D by encouraging industry to make greater use of the technical expertise and facilities of defense research establishments;
- A new emphasis on cooperation between government research bodies, higher education institutions and industry. In the United Kingdom, for example the LINK initiative was launched in December 1986 to encourage collaborative programs between the three parties in pre-competitive but industrially-relevant research.

3.14. A sharper focus on industry-oriented R&D has meant also a greater emphasis in public support on more

ES		FR		IR		IT		NL		PO		UK	
1986	1987	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
5.3	7.7	1.5	1.4	0.7	0.6	1.1	1.4	0.6	0.6	10.2	9.0	1.7	1.7
3.4	0.2	3.2	3.2	3.9	4.2	0.9	0.8	4.2	4.6	8.9	10.5	1.4	1.6
0.4	2.0	0.5	0.4	0.8	1.0	1.0	0.9	3.0	3.1	3.0	3.4	0.7	1.5
4.0	8.6	3.8	3.6	4.9	3.9	4.4	4.5	2.2	2.5	0.2	0.2	3.7	3.3
12.3	3.1	7.1	6.7	1.2	1.1	17.4	11.1	4.6	4.0	5.0	4.7	4.6	3.6
4.9	6.7	3.6	3.6	27.3	24.2	3.7	3.5	4.4	4.3	14.4	14.2	4.6	4.3
17.1	21.5	12.1	10.6	26.1	27.2	19.1	19.1	14.8	17.6	7.3	6.2	6.7	9.9
0.9	0.9	2.9	2.7	8.0	10.0	1.1	1.2	3.5	2.4	0.2	1.3	1.3	1.2
4.8	8.8	5.8	5.9	1.1	2.3	6.9	9.3	2.9	2.8			1.8	2.6
18.1	19.8	11.8	12.0	23.9	23.0	28.6	31.9	43.1	40.7	35.5	30.5	14.9	15.3
20.6	8.5	15.1	14.7	2.2	2.4	7.0	6.6	9.8	10.3	1.8	0.5	6.8	3.3
2.2	3.4	1.2	1.0			0.2	1.9	4.3	4.4	13.5	19.5	0.3	0.3
94.2	91.1	69.0	65.9	100.0	100.0	91.6	92.2	97.4	97.2	100.0	100.0	48.4	48.8
5.8	8.9	31.0	34.1	-	-	8.4	7.8	2.6	2.8	-	-	51.6	51.2
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

"down-stream" R&D, with more immediate commercial application. The picture varies a good deal across the Member States, but in many the **balance between support for basic research and applied research has shifted in favor of the latter.** Public expenditure constraints, the rising cost of much basic research, and increasing emphasis of measurable cost-effectiveness have all contributed to this trend in a process that has been dubbed "the shift from science to technology policy[25]." In some countries (France, Germany, Netherlands), non-oriented research continues to be given a high level of priority, alongside support for pre-competitive industry-oriented R&D. In the United Kingdom, on the other hand, the public funding of basic research has been downgraded relative to the financing of pre-competitive applied R&D, this reflecting a particular UK concern about the perceived difficulty of translating British intervention into innovation.

Duplication and Overlap

3.15. Outlines of the situation in each of the Member States are given in the short synopses that follow reflect the ongoing work within CREST to compare national policies and identify potential areas for cooperation. This process, which is discussed further below under **Policy Coordination**, is not yet complete. It is already clear, however, that there are areas where duplication of effort and overlap do exist. One aim of subsequent reports on the state of science and technology will be to highlight these areas.

Dual Use Technologies

3.16. One difficult question in this context is the difference among Member States in the organization of R&D on so-called "dual-use" technologies. The common features in the technological requirements of the defense and civil sectors affect several key areas: sensor and signal/image processing, complex system design and information processing, man-machine interfaces, vehicle technology, advanced design and manufacturing technology, electronics/ microelectronics/ optoelectronics/ bioelectronics, communications, advanced materials, medical technology, electrical and mechanical engineering, and energy conversion.

The development of these dual-use technologies is funded in Europe through defense and/or civil R&D programs, depending on the country and the degree of resources devoted to military R&D.

The need to improve coherence between civil and defense programs, where they overlap, in order to optimize the use of resources (manpower and financial) has been recognized at national level (cf. 3.13 above) and mechanisms are implemented in the principal countries to avoid unnecessary duplication and promote technology transfer from civil to defense and vice versa. These efforts to promote the optimal use of resources at national level are reasonably successful in some areas but more remains to be done in other areas where duplications or barriers to technology transfer remain significant.

3.17. However, the most significant duplication arises not in national programs but between European countries. To the extent that civil applications are taking the lead in driving the development of several dual-use technologies,

civil programs to promote European technological cooperation, in particular Community programs and EUREKA contribute to a more efficient use of resources. (see below) Their impact is, however, inevitably limited given their size and scope.

In those technological fields which are more driven by defense applications, much remains to be done to establish effective cooperation between countries.

Another trend which is important in discussing and harmonization of defense and civil research efforts to establish a broad competitive technology base is the escalation of the cost of developing and producing military equipment. This has led defense departments in Europe to reduce their support for some dual-use technologies and to concentrate their resources on military-specific developments (a trend observed in the United States—cf. Chapter II).

While this trend reduces the risk of duplications between civil and defense programs, it also implies that an additional effort by industry or through civil programs is needed to maintain a broad competitive technology base in Europe.

Belgium

Gross Domestic Product (GDP): 104.5 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 1,542.6 Mio ECU (est.) (1985)

GERD/GDP: 1.48 percent (est.) (1985)

National Budget: 49,112 Mio ECU (1986)

R&D Budget: 652.6 Mio ECU (1986)

R&D Budget/National Budget: 1.33 percent (1986)

Number of Researchers per 1000 Labor Force: N.A.

Percentage of GERD Financed by Industry: N.A.

Defense R&D as a percent of Total Government Appropriations: 0.2 percent

Responsible Ministry for S&T: Deputy Prime Minister, Responsible for the Budget and the Science Policy.

Structure of S&T Policy: The coordination of the whole structure is the responsibility of the Science Policy Office ("Services de Programmation de la Politique Scientifique") belonging to the Prime Minister's Services. However, a significant portion of the "Science policy budget" is the direct responsibility of the different ministries.

National Priorities:

1. More concentration of funds on selected research topics:
— informatics (Artificial intelligence, software and microelectronics);
— biotechnology and biosciences;
— aerospace;
— new materials;
— telecommunications;
— oceanography.

2. Increased support for fundamental research and more cooperation between university and industry;

3. More incentives to industry in order to increase its share (already one of the highest in Europe: about 62 percent in 1985) in the overall funding of R&D.

4. Maximum encouragement of participation in Community and international programs.

Trends: The responsible government officials state that the ratio GERD/GDP should rise from about 1.5 percent to the same level as Netherlands (about 2.3 percent) but after a budget increase in 1985 the overall funding shows only marginal increases.

Comments: The new federal structures of the Belgian State, may lead to a different share of the coordination of research among linguistic communities, regions and national authorities. However, at international level the national authority should be totally responsible for coordination.

Denmark

Gross Domestic Product (GDP): 76.4 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 959.3 Mio ECU (1985)

GERD/GNP: 1.26 percent (1985)

National Budget: 32,738 Mio ECU (1986)

R&D Budget: 508.7 Mio ECU (1986)

R&D Budget/National Budget: 1.55 percent (1986)

Percentage of GERD Financed by Industry: 48.9 percent (1985)

Defense R&D as a Percent of Total Government Appropriations: 0.4 percent (1987)

Number of Researchers per 1000 Labor Force: 3.1 (1985)

Responsible Ministry for S&T: The Ministry of Education and Research and the Ministry of Industry.

Structure of S&T Policy: Each ministry has responsibility for supporting research related to its function. The government's internal coordination of S&T policy is guided by its National Research Committee under the chairmanship of the Ministry of Education and Research and by its Industrial Policy Committee chaired by the Ministry of Industry. Both ministries have advisory councils (the council for Research Policy and Planning and the Council of Technology). The largest shares of the national R&D are funded by the Ministry of Education and Research (more than 50 percent), the Ministry of Industry (about 25 percent).

National Priorities: S&T is a top priority policy area in the mid-1980's in Denmark. Three topics have been declared:
— Information Technology;
— Material Research;
— Basic Biotechnical R&D.

Most Danish companies are small/medium-size enterprises (SME) and special government effort is necessary to aid the dissemination of information on new technology and its adoption.

Trends: Denmark ranks amongst the EC Member States which spend between 1 percent and 2 percent of the GDP for R&D. Since 1980 an increase of about 8 percent per year has been registered. The government's plans provide for a GERD of about 2.3 percent of GDP for the year 2000.

Comments: Danish research and technology rely on wide international cooperation. About 5 percent of the national R&D resources are attributed to participation in international cooperation, including the EC R&D programs. Participation in Nordic research cooperation is of importance to Denmark.

Federal Republic of Germany

Gross Domestic Product (GDP): 826.4 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditures for R&D (GERD): 22,009.4 Mio ECU (1985)

GERD/GDP: 2.66 percent (1985)

National Budget: 238,935 Mio Ecu (1986)

R&D Budget: 10,049 Mio Ecu (1986)

R&D Budget/National Budget: 4.20 percent (1986)

Percentage of GERD Financed by Industry: 60.9 percent (1985)

Defense R&D as a Percent of Total Government Appropriations: 12.4 percent (1986)

Number of Researchers per 1000 Labor Force: 4.8 (1983)

Responsible Ministry for S&T: The Federal and the Laender Governments attach importance to the freedom of research and the principles of "subsidiary funding." The Laender have mainly the responsibility for R&D in the universities (about 13 percent of 1987 total R&D); the Federal Government is responsible for non-university R&D (about 24 percent of 1987 total). The funding of the supporting bodies (DFG [German Research Association], MPG [Max Planck Society], FhG [Fraunhofer Society]) and the national research centers is shared between the Federal and the Laender Governments. The Government believes that in a free-market economy the primary responsibility for R&D is that of industry (61 percent of the 1987 total R&D). Further strengthening of performance and private initiative will be assisted by tax incentives which will be provided within the 1990 tax reform.

National Priorities:
— Increased promotion of basic research, strengthening of research with long term prospects and expansion of preventive research (ecology, health, climate);
— Promotion of industrial research in the area of market oriented technologies;
— Improvement of the basic conditions for innovation in SMEs.

More specifically: the completion of the Airbus family; information technology; materials research; biotechnology; selected physical technologies (laser, thin-film); regenerative energy technologies.

Trends: National R&D expenditure increased between 1973 and 1987 from 2.1 percent to 2.7 percent of GDP. The business sector's contribution to global R&D expenditure increased from 56 percent in 1981 to 62 percent in 1987 and is far the highest among the EC Member States.

Comments: International cooperation has a high priority in the S&T policy of the FR Germany. About 8.2 percent of the Federal Government R&D expenditure was committed to international organizations in 1987.

Greece

Gross Domestic Product (GDP): 42.8 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 148.9 Mio Ecu (1985)

GERD/GDP: 0.35 percent (1985)

National Budget: 14,763 Mio Ecu (1986)

R&D Budget: 99.5 Mio ECU (1986)

RD Budget/National Budget: 0.67 percent (1986)

Percentage of GERD Financed by Industry: 26.3 percent (1985)

Defense R&D as a Percent of Total Government Appropriations: 2.3 percent (1987)

Number of Researchers per 1000 Labor Force: 0.8 (1983)

Responsible Ministry for S&T: General Secretariat of Research and Technology, an autonomous body within the Ministry of Industry, Energy and Technology.

Structure of S&T Policy: Each ministry is responsible for its own research. The Ministry of Industry, Energy and Technology finances 43 percent of the total R&D Public Expenditure and, the Ministry of Education 29.2 percent. The GSRT coordinates the R&D efforts between the various ministries, Research Institutes, sectoral companies, universities and international organizations.

National Priorities:
— improvement of the role of the country in the international division of labor;
— establishment of institutional infrastructure for scientific and technological development;
— production of scientific and technological results of quality;
— exploitation of research results and assimilation of technology transfer;
— activation of applied and technological research for assimilation of imported technology;
— making public opinion more aware of importance of research for economic and social development.

In the new 1988-1992 National Plan, high priority is given to social and human sciences, information technology, biotechnology, and development of industrial research.

Trends: GERD as a percentage of GDP has increased steadily from 0.21 in 1981 to 0.35 in 1985. The aim is to reach 0.65 in 1992.

Comments: Greek participation in the EEC programs has increased substantially over the last years.

Spain

Gross Domestic Product (GDP): 216.2 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 1,144.4 Mio ECU (1985)

GERD/GDP: 0.53 percent (1985)

National Budget: 49.848 Mio Ecu (1986)

R&D Budget: 801.7 ;Mio Ecu (1986)

R&D Budget/National Budget: 1.46 percent (1986)

Percentage of GERD Financed by Industry: 49.1 percent (1983)

Defense R&D as a Percent of Total Government Appropriations: 5.8 percent (1987)

Number of Researchers per 1000 Labor Force: 1.0 (1983)

Responsible Ministry for S&T: The Interministerial Committee for Science and Technology composed of representatives from 9 ministries involved in research, is the official organism for the planning, coordination and follow up of national S&T policy.

Structure of S&T Policy: The National Plan defines the framework for the S&T activities of the nine ministries involved in research, whose work is coordinated by the interministerial committee. The Spanish Autonomies are quite independent in deciding and implementing their own S&T policy. Efforts have been made to coordinate those efforts at national level.

National Priorities: Priority sectors are:
— Information and production technologies.
— National resources and agro-industrial technology.
— Quality of life.

The priorities set by the national plan are, among others, the following:
— improvement of knowledge and progress in innovation and technological development;
— conservation, upgrading and optimal exploitation of natural resources;
— development and strengthening of the competitive capacity of industry, trade, agriculture and fisheries;
— strengthening of national defense;
— adaptation of Spanish society to the changes brought about by scientific development and the new objectives;
— improvement in quality of education;
— encouragement of creativity, the development and dissemination of culture in all forms;
— improvement of health, social security and the quality of life.

Trends: In Spain GERD as a percentage of GDP has increased from 0.4 in 1981 to 0.53 in 1985. The Spanish Government is determined to increase even further the national R&D efforts to levels comparable with the other advanced European countries.

Comments: In 1987, GERD is estimated to be 0.75 percent of GDP.

France

Gross Domestic Product (GDP): 674.8 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 15,587.4 Mio ECU (1985)

GERD/GDP: 2.31 percent (1985)

National Budget: 162,565 Mio ECU (1986)

R&D Budget: 10,273.1 Mio ECU (1986)

R&D Budget/National Budget: 6.34 percent (1986)

Percentage of GERD Financed by Industry: 41.4 percent (1985)

Defense R&D as a Percent of Total Government Appropriations: 31.0 percent (1986)

Number of Researchers per 1000 Labor Force: 4.1 (1984)

Responsible Ministry for S&T: Under the new Government, there is a Ministry of Research and Technology (Ministre dlgu) who is responsible for S&T policy in France. Space policy is under the Ministry of Post, Telecommunications and Space.

Structure of S&T Policy: In parallel or in cooperation with the Ministry of Research and Technology, other ministerial departments have also an important role in directing scientific and technical activities: the Ministry of National Education, of Industry, of Defense, of Economy and of PTT. Despite some considerable efforts to regionalize research, the French S&T system is centralized.

National Priorities: The first priority is the further promotion and development of industrial research. Priority will also be given to the employment of young researchers in order to solve the problem in the age structure of the French scientific body, and to training through research. The priorities in fields of research are:

— Technological Development Programs: nuclear energy, space, aeronautics, telecommunications, electronuclear equipments.

— National Programs: Biotechnology, food industry, medical research, human and social sciences, production technology, electronics, natural resources, new materials, new chemistry, research for development, research on general planning of land-use and transport.

Trends: During recent years, there has been an increase in R&D financing as percentage of GDP from 2.01 percent in 1981 to 2.31 percent in 1985. Research has been designated as a national priority for France.

Comments: In order to encourage the private enterprises to start their own research, the government has given several incentives (direct and indirect aids) for the creation of research infrastructure within enterprises and hiring of researchers by industry.

Ireland

Gross Domestic Product (GDP): 24.1 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 192.4 Mio ECU (1985)

GERD/GDP: 0.80 percent (1985)

National Budget: 14,411 Mio Ecu (1986)

R&D Budget: 115.7 Mio ECU (1986)

R&D Budget/National Budget: 0.80 percent (1986)

Percentage of GERD Financed by Industry: 45.4 percent (1985)

Defense R&D as a Percent of Total Government Appropriations: 0.0 percent (1986)

Number of Researchers per 1000 Labor Force: 2.8 (1984)

Responsible Ministry for S&T: Ministry for Science and Technology operating within Department of Industry and Commerce.

Structure of S&T Policy: In 1987 Irish S&T was considerably reorganized. Minister of State for Science and Technology was appointed and a general program of rationalization of S&T agencies undertaken. NBST [National Board for Science and Technology] and IIRS [Institute for Industrial Research and Standards] were merged to form EOLAS.

National Priorities: Strategic Research Program emphasizes application—oriented research and has identified Biotechnology, Engineering, Advanced Materials and Information Technology as priorities.

Policy aims to concentrate national S&T effort on indigenous firms. The South East Region—one of weaker R&D regions—has been declared a pilot region for S&T related economic development.

Trends: S&T has had small budget increase in 1987 despite widespread cuts in most other spending departments. Government expenditure on S&T increased in real times by 1.4 percent per annum average from 1981-1987. All Irish S&T expenditure is civilian R&D.

S&T expenditure has declined in Agriculture and Energy and increased in S&T for Manufacturing Sector.

Comments: Major S&T interests are strengthening indigenous industry S&T participation and S/T infrastructure with the help of EC structural instruments.

Italy

Gross Domestic Product (GDP): 473.0 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 6,307.3 Mio Ecu (1985)

GERD/GDP: 1.33 percent (1985)

National Budget: 275,537 Mio ECU (1986)

R&D Budget: 4,408.5 Mil ECU (1986)

R&D Budget/National Budget: 1.60 percent (1986)

Percentage of GERD Financed by Industry: 41.0 percent (1986)

Defense R&D as a Percent of Total Government Appropriations: 8.5 percent

Number of Researchers per 1000 Labor Force: 2.7 (1986)

Responsible Ministry for S&T: Ministry for S&T Research

Structure of S&T Policy: The Ministry for S&T Research will become "Ministry for the University and S&T Research," responsible for all Government funded research.

National Priorities:

1) Increase in overall funding of Government and private enterprises since 1980.

2) Emphasis and increased funds for research on new technologies such as:
— biotechnologies and fine chemicals;
— information technologies;
— new materials;
— nuclear fusion;
— telecommunications;
— optics and lasers;
— advanced transport;
— satellites and space crafts;
— biomedical instruments

3) Decrease in funds for nuclear R&D for the production of electricity.

Trends:
— The new Ministry for University and S&T Research should lead to streamlining the whole Government R&D structure and simplify the administration of Government research establishments.
— Incentives (mainly fiscal) for private funded R&D.
— The ration GERD/GDP was 0.74 percent in 1980; by 1987 it was about 1.40 percent.
— Increased European and international cooperation.

Comments: Italian authorities wish to bring the ratio of GERD/GDP to same level of Italy's largest European partners (France and UK) in 4 or 5 years.

Luxembourg

Gross Domestic Product (GNP): 4.7 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): N.A.

GERD/GDP: N.A.

National Budget: 2,005 Mio ECU (1987)

R&D Budget: N.A.

R&D Budget/National Budget: N.A.

Percentage of GERD Financed by Industry: N.A.

Defense R&D as a Percent of Total Government Appropriations: N.A.

Number of Researchers per 1000 Labor Force: N.A.

Responsible Ministry for S&T: Ministry for National Education and Youth.

Structure of S&T Policy: Interministerial Committee for Coordination of Research and Technological Development.

National Priorities:
— Setting up Government structures and public research centers to carry out R&D activities with Government funds.
— Transfer of results of research, gathered in public research establishments, to industrial innovation.

Trends: A new law (March 1987) will initiate the establishment of a certain number (up to 6 or 7) of Public Research Centers; two centers are already operational in 1988.

Comments: Luxembourg does not collect at present data on R&D expenditure but will do so probably in 1989. R&D activities have been carried out until recently exclusively in private industrial concerns, this should change with the establishment of the government-funded public research centers mentioned above.

Portugal

Gross Domestic Product (GDP): 27.3 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 111.7 Mio ECU (1985)

GERD/GDP: 0.41 percent (1985)

National Budget: 8,801 Mio ECU (1986)

R&D Budget: 91.5 Mio ECU (1986)

R&D Budget/National Budget: 1.04 percent (1986)

Percentage of GERD Financed by Industry: 30.8 percent (1984)

Defense R&D as a Percent of total Government Appropriations: N.A.

Number of Researchers per 1000 Labor Force: 0.8 (1984)

Responsible Ministry for S&T: Ministry for Planning and Territorial Administration. JNICT is the major planning, policy and overall coordination body with responsibility for preparation of R&D Budget.

Structure of S&T Policy: Since 1986 and the establishment of the Superior Council for Science and Technology there has been major changes and much new investment in S&T.

National Priorities: Priorities of the Government program (April 1987) for R&D are applied research related to users, strengthening basic research in universities, promoting mobility in science, and developing joint mobilization programs between research and industry, as well as strengthening public sector S&T infrastructural capability. Major Sectoral Research Action programs are biotechnology, robotics/microelectronics, material sciences and, marine sciences.

Trends: R&D Expenditure in 1986/87 doubled 1985's allocation with plans to steadily increase it to reach 1 percent of GDP by 1990. JNICT's budget has been increased three fold. Less than 1 percent of firms perform R&D. R&D expenditure by firms in 1987 represented 1.5 percent of national R&D expenditure. Private Non Profit Institutions accounted for 8.4 percent of R&D expenditure.

Comments: Low level of International R&D Participation but set to increase steadily with EEC membership and priority given by Government. A major priority is to strengthen S&T infrastructure as well as education and learning of S/I researchers.

The Netherlands

Gross Domestic Product (GDP): 165.3 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 3,492.6 Mio Ecu (1985)

GERD/GDP: 2.11 percent in 1985 (2.40 percent estimate for 1988)

National Budget: 70,599 Mio ECU (1986)

R&D Budget: 1,704.9 Mio ECU (1986)

R&D Budget/National Budget: 2.40 percent (1986)

Percentage of GERD Financed by Industry: 50.2 percent (1985)

Defense R&D as a Percent of Total Government Appropriations: 2.6 percent (1988)

Number of Researchers/per 1000 Labor Force: 3.7 (1983)

Responsible Ministry for S&T: The Ministry of Education and Science and the Ministry for Economic Affairs.

Structure of S&T Policy: Decisionmaking is based on a broadly structured network of advisory bodies. S&T Policy is prepared by the Council for Science and Technology Policy (RWT), chaired by the prime minister within which the minister of education and science acts as coordinating minister for science policy and the minister of economic affairs as coordinating minister for technology. The policy is market-oriented, aiming to improve competitive strength of the Dutch industry via the broadening of the technology base of the industry, improving the quality, the use, and the diffusion of technology.

National Priorities: The dissemination of knowledge via innovation centers and major incentive schemes:

— The innovation Stimulation Scheme (INSIIR) provides grants for R&D labor costs whether in-house or contracted R&D.

— The Technological Development Credit Scheme (TDC) offers support for R&D on new products. Processes, and services on condition that they are technologically new and risky.

— the SME Business Research Program (OMK) stimulates SMEs to carry out advanced R&D projects.

The Innovation-Oriented Programs (IOPs) include among others: Biotechnology, Membrane Technology, Technical Ceramics, and IC Technology.

Trends: National R&D expenditure increased between 1980 and 1988 from 2.03 percent to 2.40 percent of GDP. The business sector increased its contribution to global R&D expenditure from 50.2 percent in 1985 to 55.3 percent in 1988.

Comments: The "Internationalization of Education and Research" is a major issue in the Dutch S&T policy.

United Kingdom

Gross Domestic Product (GDP): 595.0 Billion ECU (at current prices and exchange rates) (1985)

Gross Domestic Expenditure for R&D (GERD): 13,837.6 Mio ECU (1985)

GERD/GDP: 2.33 percent (1985)

National Budget: 223,312 Mio ECU

R&D Budget: 6,786.8 Mio ECU (1986)

R&D Budget/National Budget: 3.04 percent (1986)

Percentage of GERD Financed by Industry: 46.1 percent (1985)

Defense R&D as a percentage of Total Government Appropriations: 50.9 percent (1987)

Number of Researchers per 1000 Labor Force: N.A.

Responsible Ministry for S&T: Cabinet Office has overall responsibility reporting to prime minister but ministerial departments have responsibility for own R&D.

Structure of S&T Policy: S&T structure has been strengthened into central structure under prime minister, with the Advisory Council on Science and Technology (ACOST) as expanded advisory body. The S&T Assessments office assists departments, research councils and university in R&D expenditure proposals.

National Priorities: Three main priorities have to be considered at the national level:
1. maintain and enhance quality in S&T;
2. increase social and economic return from S&T;
3. improve management, ensure greater concentration and selectivity of S&T activities.

As regards sectoral research, action programs are developed by individual ministries.

Government is conducting "searching review" of R&D priorities across Government with emphasis on contribution of Government funded R&D to efficiency, competitiveness and innovative capacity.

Criteria revised in 1987 for distribution of Science Budget.
1. Internal Funds—Timeliness and Pervasiveness.
2. External—Exploitability. Applicability and Significance for Education.
3. Financial—Benefits and Costs/Affordability.

Trends: Overall level funding for 1987-89 committed with cuts in defense research and small increases for Research Council and University Grants Committee. UK Government is determined to secure greater Industry funding of R&D, and also to ensure that industry takes more responsibility for R&D. Emphasis has shifted from project support to collaborative research.

Comments: Main concern is to ensure value for money in all research and development, international as well as national, to which UK Government contributes.

(ii) European Cooperation

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 47-51

[Text] 3.18. Examples of collaborative research ventures in Europe can be traced back over many years. CERN (the European Organization for Nuclear Research) was established in 1953; ESRO (the European Space Research Organization) and ELDO (the European Launcher Development Organization), which were later merged to the European Space Agency (ESA) were set up in 1962, the same year as the signature of the Anglo-French Concorde project; 1970 saw the establishment of Airbus Industrie.

3.19. At the level of the European Community the first collaboration in coal and steel research began in 1955, this to be followed by cooperation on nuclear research under the Euratom Treaty in 1958. In the aftermath of the doubling of oil and energy prices in 1973/74 the Community's research efforts were extended in 1974 into the on-nuclear energy fields, the environment and raw materials. In 1971 the first cooperation within the COST framework was begun, involving the Community and other European countries; COST remains an important framework for cooperation on specific projects.

3.20. But the 1980s have witnessed a qualitative and quantitative development in Community activity, characterized by the introduction of more industry-oriented "second-generation" R&D programs, medium-term resource planning for Community research, and Community level actions both upstream of research (in the field of education and training) and downstream support for innovation.

Underpinning this cooperation now is the political commitment of the Community, enshrined in the Single European Act:

— to strengthen the scientific and technological basis of European industry and to encourage it to become competitive at the international level;

— to encourage and support cooperative efforts between industry and research centers and universities;

— and to adopt a Framework Program as a medium-term planning tool.

By laying down the objectives, priorities and expected financial requirements for the Community's activities in the fields of RTD and breaking it into lines of action, the Framework Program forms a guide for specific program decisions. Another of its aims is to familiarize scientific institutions and companies with the research opportunities offered by the Community in the medium term.

3.21 The main elements in the program for 1987-1991 are given in the following table, which illustrates the emphasis given to information technologies, telecommunications, the modernization of Community industry, biotechnology, marine Science and Technology, alongside the long-standing collaboration in nuclear fusion and fission and the environment.

3.22. The largest single program is now ESPRIT, which was launched in 1984 with the aims of providing the European information technology industry over the subsequent 10 years with the basic technologies required to meet the competition of the information technology, and contributing to the development of internationally accepted standards. For its first 5 years the ESPRIT program has a total budget of 1500 MECU, half of it funded by the Community, and half by the research partners themselves. In its second phase ESPRIT has a budget of 3.200 MECU, again shared equally between the Community and the research partners. The first phase of the program concentrated on pre-competitive research in micro-electronics, information processing systems, and application technologies such as computer aided manufacturing systems. The new phase includes, alongside the application-orientation, some emphasis on more basic research targeted on issues such as artificial intelligence.

3.23. The second largest group of industry-oriented activities aims at the modernization of European industry through the use of advanced technology and the development of new materials. Here the BRITE program is the largest single element. BRITE was launched in 1985 as a 4-year program funded jointly by the Community (185 MECU) and research partners in universities or industry. Building on its experience with the BRITE program and the related EURAM [European Research on Advanced Materials] program on advanced materials (under which together some 300 projects are being financed) the Commission has recently submitted proposals for a new combined program for 1989-92, which is designed to attract SMEs in particular and which, it is estimated, could generate projects costing 1.000 million ECU. Most of the Community funding of 440 MECU will be on applied research, but up to 7 percent of the budget will be made available for more fundamental work in areas where industrial progress is hindered by weakness in basic sciences.

3.24. A third element in the Framework Program which has a specifically applied industrial orientation is RACE which is designed to ensure that the different telecommunication systems and services now being developed in Europe remain consistent. The specific aim of the RACE program is to enable the Community to move towards integrated broadband communications based on integrated digital networks in a system able to handle a wide range of new and conventional telecommunication services from telephones to videophones, cable TV, data transmission and contribution to the Community's development strategy for the telecommunications sector as a whole, which will be of great importance of the functioning of the internal market.

Table 3.7. Framework Program Of Community Activities in the Field of Research and Technological Development—1987-91 (Breakdown of the amount deemed necessary between the various activities envisaged)

	Million	ECU
1. Quality of life		375
1.1. Health	80	
1.2. Radiation protection	34	
1.3. Environment	261	
2. Towards a large market and an information and communications		2,275
2.1. Information technologies	1,600	
2.2. Telecommunications	550	
2.3. New services of common interest (including transport)	125	
3. Modernization of industrial sectors		845
3.1. Science and technology for manufacturing industry	400	
3.2. Science and technology of advanced materials	220	
3.3. Raw materials and recycling	45	
3.4. Technical standards, measurement methods and reference materials	180	
4. Exploitation and optimum use of biological resources		280
4.1. Biotechnology	120	
4.2. Agro-industrial technologies	105	
4.3. Competitiveness of agriculture and management of agricultural resources	55	
5. Energy		1,173
5.1. Fission: nuclear safety	440	
5.2. Controlled thermonuclear fusion	611	
5.3. Non-nuclear energies and rational use of energy	122	
6. Science and technology for development	80	80
7. Exploitation of the sea bed and use of marine resources		80
7.1. Marine science and technology	50	
7.2. Fisheries	30	
8. Improvement of European S/T Cooperation		288

Table 3.7. Framework Program Of Community Activities in the Field of Research and Technological Development—1987-91 (Breakdown of the amount deemed necessary between the various activities envisaged)

	Million	ECU
8.1. Stimulation, enhancement and use of human resources	180	
8.2. Use of major installations	30	
8.3. Forecasting an assessment and other back-up measures (including statistics)	23	
8.4. Dissemination and utilization of S/T research results	55	
Total		5,396

3.25. Other sectors too now have a significant applications-oriented component. The Community's biotechnology program (BAP—Biotechnology Action Program), notably covers a number of research fields relevant to the needs of industry and agriculture and is complemented by a program of projects specifically for the application of biotechnology to agro-industry.

3.26. Alongside the part-funding of contract research in these and other areas of the Framework Program and the work of the Community's own Joint Research Center (which is itself now to have a more industry-oriented vocation) the Community is:

- promoting **cooperation and exchanges of research scientists** among the Member States through the SCIENCE program (formerly called the STIMULATIO program);
- encouraging **student mobility** and cooperation between **higher education institutes** in Europe through its ERASMUS program;
- promoting strong and long-lasting **partnerships between enterprises and universities in training, notably** in respect of high technology (COMETT [Community in Education and Training for Technology]);
- promoting the effective **dissemination of the results from its research activities** and contributing to their application through the VALUE program;
- working towards the **lowering of languages barriers** to the circulation of information through the EUROTRA program;
- encouraging **innovation** through the SPRINT [Strategic Programme for the Transnational Promotion of Innovation and Technology Transfer] program which aims to create more favorable conditions for innovation and technology transfer in general, as well as other sectoral programs such as STAR [Space Technology and Advanced Research] (telecommunications) and VALOREN (energy technologies) which are specifically oriented towards the needs of the less-developed regions of Europe;
- promoting the **application of new information and communication technologies** in order to develop the information services market, through the IMPACT program and through sectoral programs (AIM [Automated Information Management], DRIVE, DELTA [Distributed Electronic Test and Analysis]).

3.27. The experience of the Framework Program activities both under the current program and under the first program (1984-87) has been overwhelmingly positive, demonstrating a real thirst for cross-border cooperation. The enthusiasm generated by the Community programs in the industrial and higher educational worlds is indisputable. The ESPRIT [European Strategic Programs for Research and Development in Information Technology] and BRITE [Basic Research in Industrial Technologies for Europe] programs, in particular, have been massively oversubscribed, with the Commission and its Advisory Committees having to turn down for support a large number of potentially good projects. The same is true of programs such as ERASMUS, which has been oversubscribed by a factor of at least three and COMETT (which in 1987 received applications for 120 MECU compared with available finance of 16 MECU). The clear evidence is that the provision of a framework encouraging cooperation and collaboration in Europe in the scientific and technological fields responds to a widely-felt need, particularly at a time when pressures on national funding have been growing.

3.28. The experience of the EUREKA initiative also confirms the growing interest in European collaboration as a means of improving Europe's technological base and making the most of the opportunities offered by the Internal Market.

3.29. Since EUREKA was launched in 1985, 213 cooperative cross-border projects have been announced in the fields of information technology, robotics, biotechnology, communications equipment and other high technology fields. These include, most notably, the High Definition Television Project, a major set of projects in the area of flexible automated assembly (FAMOS [Fleet Application of Meteorological Observations from Satellites]), as well as projects in the transport and environmental research field. The total EUREKA project portfolio has currently an estimated value of some 3.8 billion ECU, which is equivalent to around 1 billion ECU per year (about half the level expected to be generated by the Community programs); and already some 800 organizations—two-thirds of them industrial—are involved. While some of these collaborative industrial projects, which are intended to be more "downstream" than Community projects, might well have gone ahead even in the absence of the EUREKA framework itself, the number of projects coming forward confirms the growing industrial and university interest in collaboration and cooperation. In the case of EUREKA, cooperation has the added dimension of facilitating cooperation between companies and institutes in Community Member States, on the one hand, and those in the EFTA countries in particular, on the other—around half the EUREKA projects involve participants from each grouping[26].

3.30 EUREKA is an important complement to the Community's own activities in support of the objective of improving the mastery of new technologies. The Commission plays a full role inside EUREKA on behalf of the Community in an effort to maximize the synergy between the two groups of research activity. It has recently outlined ways in which cooperation between the Community and EUREKA can be reinforced without prejudicing the operation of the Community's own R&D programs themselves[27].

(iii) Policy Coordination

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 51-52

[Text] 3.31. The Community programs (currently about 1.000 million ECU a year) are small compared with the R&D budgets of Member States (over 35.000 MECU in 1986); and the total cost of projects supported through the programs is only equivalent to about 4 percent of total estimated public and private spending on civil research (about 50 billion ECU per year). Even if all the other European collaborative actions are taken into account—EUREKA, COST, ESA, CERN, EMBL etc.—**the bulk of research continues to be financed and carried out at national level,** a large share of it through the national budgets discussed earlier. Given the pressures on resources and the risks of fragmentation and duplication of effort it has been recognized by European governments that better coordination of national policies is now required. That recognition is reflected in Article 130H of the Single European Act which promises better coordination.

3.32. There are a number of factors which have constrained coordination to date. These include: the different R&D capacities among Member States; the different balance between civil and military R&D; different patterns of involvement by the public and private sectors; different traditions in higher education; different sectoral priorities reflecting in part specific economic and social concerns (eg. energy in Italy, the environment in Germany).

Broad policy coordination is at present limited to the exchange of better mutual information about programs and policies under way and exchanges of views among scientific advisors and experts in the Advisory Committees of Community programs; while specific coordination efforts are reflected in the concerted actions in the fields of medical research and the environment and, together with other European countries, within the framework.

3.33. The pressures of the Internal Market will militate in favor of further policy coordination among Community Member States through the need to develop common standards, the opening up of public procurement, the requirements of competition policy. The framework for intergovernmental cooperation provided by EUREKA will also push in the same direction: intergovernmental coordinating committees already exist for some of the larger projects and aim to provide a framework for dealing with the problems of concerted government actions which will be a necessary corollary to research cooperation. But the degree of coordination is likely to remain patchy unless the commitment reflected in Article 130H of the Single European Act is vigorously pursued.

The Commission attaches particular importance to the ongoing work within CREST designed to facilitate an in-depth exchange of information on national policies and thus to help identify duplications and overlaps. As noted earlier, it intends to focus particular attention on this question in forthcoming reports on the state of science and technology in Europe.

A great deal has already been done, both at a national and a transnational level, to tackle Europe's problems. The success of the Community's RTD programs, the rapid development of EUREKA, other bilateral and multilateral ventures inside Europe, have demonstrated that there is a thirst for cooperation across national frontiers and that it can be mounted successfully, despite the barriers of cultural and linguistic differences.

But policy coordination among the Member States of the Community is still weak and particular efforts are needed to reduce the potential for duplication and overlap in national efforts. Dual-use technologies pose particular problems in this respect.

IV. Research Issues for Future

Challenges Facing Community

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 53-54

[Text] 4.0. Three main challenges face the Community:

- to improve its international competitiveness, notably in the context of the completion of the Internal Market;
- to respond to the needs of society by improving the quality of life; and
- to increase its capacity to pursue its own scientific and technological options where necessary, by reducing its dependence on others.

These three goals are interlinked. By improving competitiveness the Community will create the wealth which makes it easier to tackle issues of social concern. Technological independence, on the other hand, is linked to longer-term competitiveness, with fundamental research offering opportunities to increase the scope for determining, rather than simply responding to economic change in an international context.

4.2. The organization of this chapter reflects these three concerns by dealing, **firstly,** with the research requirements to improve competitiveness; **secondly,** with the areas where research has a particularly important contribution to make in meeting Europe's social needs; and **thirdly,** with the scientific and technological base of

fundamental research, which provides the essential underpinning and the seedcorn for the longer-term.

There are, inevitably, overlaps between and among these categories. The most obvious is in the case of the biological sciences which will make significant economic and social contributions (through their impact on industry and agriculture, on the one hand, and in the fields of health and environment, on the other), and where progress on specific questions of fundamental research is essential if major break-throughs are to be achieved. The categories chosen, however, reflect the areas where the most significant contributions can be expected form individual areas of research.

4.3. Under each heading the chapter considers the market situation, the research needs and action underway in Europe (in industry, at Member State level and, where appropriate, within the framework of the European Community). The industrial and services markets are analyzed separately in depth in the **"Panorama of EC Industry"** which is shortly to be published by the commission.

4.4. This is a first analysis of the main research needs, which the Commission intends to refine during the coming months. But it already reflects a wealth of inputs and advice from inside and outside the Community institutions; the main contributions have already been indicated in the Introduction to the report. It was not possible in such a short report to be exhaustive. The report concentrates on the areas where the needs are most clear.

1. Improving Competitiveness

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 54-55

[Text] 4.5. There is a broad consensus internationally on the areas of technology which are expected to be important for industry and the services over the period to the end of the century.

4.6. As underlined in Chapter I, the new groups of technologies are not independent of each other. Lasers, for example, which are developed from opto-electronics, are used for cutting and milling metals and plastics, composites and ceramics. On the other hand silicon and, for the future, superconductors are materials on which improvement in electronic components depend, while superconductors may modify significantly the way energy is transported and stored. Some of interrelationships are identified by the concentric circles in Table 4.2.

Table 4.1. Emerging Technologies

Japan	USA	EC
Electronics	Electronics	Information Technology
Software Engineering	Automation	New Materials
New Materials	Computing	Biotechnology
Biotechnology	Advanced Materials	Energy
Biomaterials	Medical Technology	
	Thin Layer Technology	

Sources:
—The Status of Emerging Technologies: an Economic/Technological Assessment to the year 2000. U.S. Department of Commerce, June 1987
—Trends and Themes in Industrial Technologies, MITI, 1988—Panorama of EC Industry 1989 (forthcoming publication by the EC Commission)

Specific research needs in Europe can, however, be identified in five fields:

1. Information Technology and Telecommunications, where Europe has made substantial progress, but where rapid developments are occurring world-wide;
2. Industrial Materials Technologies, which are vital to the success of manufacturing industry;
3. Aeronautics, where Europe faces a particularly important competitive challenge;
4. Biological sciences, which are the focus of attention world-wide and which offer the prospect of radical improvements in agricultural and industrial production and major commercial opportunities, in addition to their impact on medicine and the environment;
5. Energy, where adequate and secure supply at reasonable cost and in a environmentally acceptable form is an essential prerequisite to the functioning of the European economy.

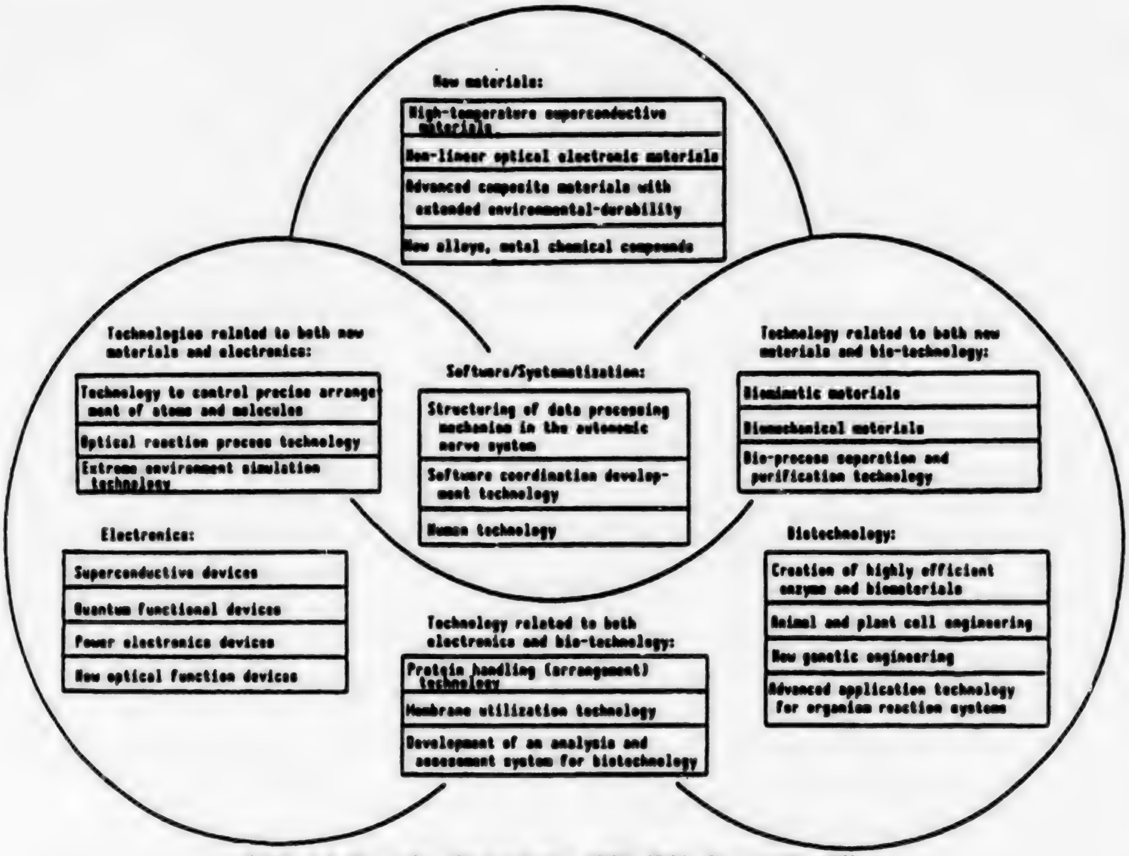


Table 4.2. Emerging Technologies With Wide Penetration Effect.
Source: Japanese White Paper on S&T. 1988. MITI.

Information Technology, Telecommunications

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 55-61

[Text]

The Market Situation

4.7. Europe's weaknesses in this area, especially in the **information technology** industry, attracted great concern at the beginning of the 1980s. The European industry was characterized by a flagging IT market, low market shares, low R&D and low Capital Investments. Moreover, the balance of trade in IT products was negative, amounting to a deficit of 10.6 billion U.S. dollars in 1984.

Concerted action was taken from 1984 onwards by the European companies to rectify the position. These actions encouraged a new dynamism in the European industry and helped mobilize human, financial and technological resources which were supported by collaborative programs such as ESPRIT. The fruits of these combined efforts are just starting to appear:

— In a world-wide market growing at more than 15 percent yearly, the six main European companies have been growing at 25 percent p.a.

— In the European market, the largest European companies have significantly increased their market share, bringing it close to 50 percent from 33 percent in 1983.

—In software and services market, the European companies are holding a favorable position, taking advantage of the strong growth of the market demand.

—European IT companies are now investing in R&D a proportion of their sales that is very close to that of U.S. companies. Nevertheless the needs for R&D in the IT field are accelerating.

4.8. Although the European Information Processing industry seems on the way to overcome some of its traditional weaknesses, major problems still remain. These include:

— The penetration of European Information Systems companies on overseas markets is still minimal (15 to 25 percent of sales).

— The balance of trade in IT products has not improved. On the contrary in 1986 the trade deficit increased to 13.4 billion U.S. dollars.

— The Electronic Components industry has not progressed in Europe at the same rate, making the Information Systems industry and other user industries even more dependent on foreign suppliers of critical and strategic components (Table 4.3.).

— The situation is similarly critical in certain types of computer peripherals. These represent an ever-increasing share of the value of Information Systems.

— A major weakness in Europe is the lack of trained personnel.

Table 4.3. Electronic Components—Main Trends—1980-1987 (Million ECU; EUR-12)

	1980	1985	1986	1987
Apparent Consumption	6,083	13,125	13,117	n.a.
Net Export Earnings	+1,246	+104	+498	n.a.
Total Production	7,329	13,229	13,615	14,060

Source: Panorama of EC Industry 1989

Note: By comparison, the U.S. has a components market worth more than 29 billion ECU in 1986, and Japan 23 billion.

4.9. The relative success in some areas of European IT serves to highlight the remaining problems. Continued action is also required to consolidate the newly acquired competitive positions. This means:

— ensuring the economic climate and boundary conditions which allow full exploitation of the potential demand;

— strengthening European technological capabilities in key areas.

4.10. **In the telecommunications sector** the relatively favorable situation of Europe, in industrial, technological and commercial terms could be threatened by:

— the continuing weaknesses in the field of electronic components;

— new technological and market challenges (digitalization of networks, ISDN and broadband networks);

— the spiralling costs of R&D in telecommunications;

— the effects of rapid changes in the regulatory environment world-wide.

Substantial efforts are therefore needed to secure and to reinforce the present position of European industry and telecommunications operators.

Research Needs: Information Technology

4.11. Further advances in the field of **electronic components** will lead, for example, to an increase of the capacity of memory chips beyond the present state of the art (1 Mbit). Progress towards the objective of 64 Mbit chips make it necessary to design circuitry for feature sizes below the level of 0.5 micron. This requires highly sophisticated design and production techniques. The new technological approach, combined with the currently stronger industrial and technological position of the European semiconductor companies, should provide opportunities for Europe to come back into the race. A significant cross-border collaborative effort in Europe is proposed under the Joint European Submicron Silicon project (JESSI), which aims to develop the design and manufacturing techniques needed for Europe to change its competitive position vis—vis the United States and Japan. This project will need appropriate support from companies and public authorities.

4.12. At the same time progress needs to be made in **software and advanced information** processing, given the growing demand for increased capabilities for computing, for knowledge—(rather than data-) processing, and for enhanced user friendliness.

Key issues in this context are: operating systems; management systems for data base; parallel architectures which can provide powerful computing capabilities (Europe has very good capabilities in this field); RISC architectures, especially for microprocessors.

The traditionally good technical position of Europe in the software area is being reinforced by the advances made through some major cooperative projects developed in ESPRIT. Further efforts are nevertheless required if Europe wants to stay in the race: The United States and Japan (especially through ambitious long term projects such as TRON, SIGMA, 5th Generation...) are making major efforts in this field.

4.13. **Peripherals** will become increasingly important with the development towards integrated systems. Research work on flat panel displays and optical storage technologies is progressing fast; but Europe's situation is rather weak and requires early attention.

4.14. At the same time as this applied research effort, however, the fast-developing IT industry is demonstrating a need for more **fundamental research** in computer services (to solve problems of reliability, safety and security); in programming languages appropriate to the

expanding hardware facilities; in machine-learning; in areas such as the design of autonomous mobile robots, cognitive engineering, and specifically the analysis and better design of human-computer-work interactions.

4.15. Finally, there are major needs in the field of **prenormative research,** because of the increasing importance of standards (and of their early definition of standards) in the context of evolution towards the integration of complex systems designed for a wide range of new applications (intelligent banking and financial services; advanced robotics; multimedia systems; bioinformatics; intelligent car and transportation systems; home automation...).

Research Needs: Telecommunications Technologies

4.16 The key issues in telecommunications are essentially related to the establishment of broadband networks, equipment and services, which are expected to happen from the mid-1990s onwards (the present narrow-band ISDN network, which will use technologies already available, requires basically standardization work).

Most technological developments are therefore generated by demand pull, linked to each major component of the broadband communication system:

a) **broadband infrastructures** will carry information flows 1000 times more important than today.

This will require enhanced systems of network management using the resources of advanced information processing and of data base management systems. The United States are presently ahead in these areas.

b) **broadband equipment** will develop according to three technological stages allowing each time considerable gains of speed, of volume transmitted and received and of cost effectiveness. These three stages will use:

— VLSI electronic components for switching; coding-/decoding; network management.

  The design and use of these components require strong advances to be made in the field of software. Here Europe is still behind the United State and Japan;

— optoelectronic components which will allow better and quicker interfaces with fibreoptics transmission;

— optical communication (operational after 2000) which implies: new materials for components; new component manufacturing technologies; new software tools in order to control and manage considerable flows of information transmitted at very high speed (coherent multichannel techniques allowing multiplexing of optical channels on one fibre by frequency allocation).

c) **broadband services**

Their implementation requires substantial activity in:

— service engineering techniques, (covering issues of standardization, software, expert systems, data libraries, image processing), in order to establish operational services able to combine data, images and voice through merging of data processing and telecommunications. The 3 main regions of the world seem to be at the same stages in this field;

— appropriate exploitation of technologies through increased activity test beds, language customization of hardware and software, permanent feedback with the users of new services, in order to provide advanced/intelligent terminals for specialized business use and for domestic use (by combination of PCs, TVs, hifi...).

Research Needs: Application Technologies

4.17. The convergence and maturing of information technologies, telecommunications and audio-visual services has created conditions favorable to the intensive exploitation of the basic technologies, adapting them to the specific needs and constraints of different categories of users (the business world, public administration, social services, individuals) in order to meet social and economic needs.

4.18. The fields of potential application are very numerous: health, transport, agriculture, public administration, education and training. And the spread of technologies to be used and integrated in this respect is broad: personal computers, optical discs, microprocessor cards, new medical and educational imaging techniques, computer languages close to ordinary human language, expert systems, mobile telephones, integrated digital services, broad band networks, high definition television, direct satellite transmission, etc....

The problem is to combine and integrate as far as possible the broad range of technologies already available or under development; and to optimize their overall performance in technological, economic and social terms, while avoiding the risks caused by the present proliferation of independent systems which are conceived from particular, and often exclusively national perspectives. Avoidance of such risks requires cooperative and concerted actions at a European level among all the actors concerned.

4.19. In Europe there is a particular need to make use of the opportunities offered by information technology to facilitate the flow of information across linguistic boundaries. This is particularly important to the Community's service and distribution industries, which currently represent 59 percent of GDP and 60 percent of employment in Europe. It will be of increasing relevance in the context of the completion of the Internal Market. The

current EUROTRA program at Community level, which began in 1982, has already produced a sound basis for the creation of a European language industry. But new efforts are needed to:

(a) encourage industrial participation in the development work and knowledge transfer between universities and industry;

(b) exploit the results of research on artificial intelligence, voice and pattern recognition and expert systems developed under programs such as ESPRIT. The transformation of ongoing pre-competitive research into industrial applications will lead to increased outlets and demand for normally "monolingual" natural language processing technology such as text processors, hyphenation, grammar and spelling checkers, optical readers and the like, thus providing further impetus for the growth of the information technology industry.

European Action in IT and Telecommunications

4.20. Assuring the necessary and most effective efforts on R&D in these fields will require further encouragement and coordination at European level. Action is a already under way in some areas. The second phase of ESPRIT is now in operation. And in the field of sub-micron technology, as noted above, discussions are in progress between European manufacturers to establish an appropriate framework for research (the JESSI project); the Community will have a role to play as catalyst.

With Eureka, information technology projects represent a major share of the project portfolio. It will be important to capitalize on the successful experience of European collaboration in the information technology field and to ensure the best possible coordination between projects and programs.

4.21. As far as more basic research on IT is concerned, Europe is in a different position from its competitors. In the United States and particularly Japan, such research is largely the preserve of industry; while in Europe industry has been more short- or medium-term oriented. This is an area where action at a European level can be of immense value in encouraging the necessary work to be carried out in a cooperative framework and in helping to commit industrial finance to the projects.

Industrial Materials, Technologies

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 61-65

[Text]

The Market Situation

4.22. Industrial technologies support the design, engineering, manufacture and operation of products and processes. They are inseparable from the materials which must be developed, processed and finished to meet the designer's intentions.

4.23. The primary customer for industrial technologies and materials is manufacturing industry, which currently provides about 30 percent of GNP in the European Community, and 75 percent of the industrial work force of some 41 million people. The Community balance of external trade in manufactured goods—+15 percent in 1987—is positive.

Table 4.4. EC Trade Balance in Manufactured Goods (billion ECUs)

	Imports	Exports	Balance
1981 (EC 10)	171	236	+65
1987 (EC 12)	252	289	+37

Source: EUROSTAT

Moreover, some of the traditional sectors of manufacturing have invested heavily in new technology in the past few years: the textile industry is the most telling example, with great confidence in the industry that the move towards computer-integrated manufacturing is likely to reinforce its position on world markets (the EC accounts for 55 percent of world production). Despite the improving position in many areas, however, Western Europe suffers form structural weaknesses, namely an inadequate capacity to respond to growing demand in some of the more developed markets—particularly those where the economies of scale are largest, such as transport equipment, machinery, instrument manufacturing, paper and printing.

4.24. Successful manufacturers are seeking increasingly to capture the top end of the market by new and improved products, usually with a higher technology content in the product itself or in its means of manufacture. The potential for increased productivity and flexibility is particularly great in the "mature" industries (such as textiles, clothing, motor vehicles and food as well as textiles). Improving the situation depends heavily on the further diffusion and application of available technologies by these industries. It also depends, however, on advances in the technologies themselves and in exploiting the possibilities that they offer. Progress in R&D is therefore fundamental to long-term success. Here Europe is hampered by the low level of industrial R&D compared with that of the United States and Japan (a point underlined in Chapter II and III).

Research Needs

4.25. Particular areas that require renewed research efforts are:

- The development of technologies to improve product and process quality and reliability. Ensuring quality

and reliability can typically cost 5-25 percent of company turnover, and for one Member State has been estimated to cost the equivalent of 10 percent of GNP. Significant improvements are possible through successful R&D on optical engineering, sensors, power control engineering and through the use of modelling in areas such as the filling of complex injection molds, particle formation in atomizers, positioning of sensors for monitoring, or the design of composite materials;

- Techniques for shaping, joining and assembly, and for surface treatment. The prevention of corrosion, which is estimated to cost 4 percent of GNP in industrialized countries, makes progress in surface treatment potentially of real economic significance;
- Catalysts and membranes. Progress in the understanding of catalysis could lead, in particular, to cleaner production through higher specificity; while the world market for membranes (currently estimated at 400 MECU/year) is likely to grow significantly as new applications are identified.
- Powder technology. This is a large and high-value market (about 2 billion ECU/year in the United States, half as big in Europe and Japan). While steel, semi-finished powder and metallurgical components can be valued at between 20-50 ECU/kilo, ceramic powder parts can cost 2.000 ECU/kilo. International competition is particularly strong, driven in part by the requirements and spin-offs, such as vacuum technology, from the space programs;
- Other high-value materials, such as metal matrix composites (already being developed for ceramic-reinforced light alloy pistons) and anisotropic materials using various strengthening techniques such as particles or fibre reinforcement;
- Superconducting materials.

In information and communication technology the further development of superconducting materials could lead to qualitative breakthroughs (by minimizing heating), as well as progress in technologies based on magnetism (e.g. fast switching devices, nuclear magnetic resonance for medical diagnosis, controlled nuclear fusion). And if economic devices carrying high current densities could be built, long distance electricity distribution networks and magnetic superfast trains would acquire a more practical dimension.

Some very fundamental aspects of superconductivity, however, are not yet understood and the prospects for development of high current density devices are still uncertain. In Japan around one-third of the research effort is devoted to work on these issues.

In Europe, where some of the seminal discoveries were first made, reactions to the explosion of interest in the field was rapid (the EC Commission convened the first group of interested experts in June 1987). But in terms of resources made available the European response was much weaker than in the United States and Japan.

In order to match the financial, technological and human resources made available by competitors, systematic joint European action is needed.

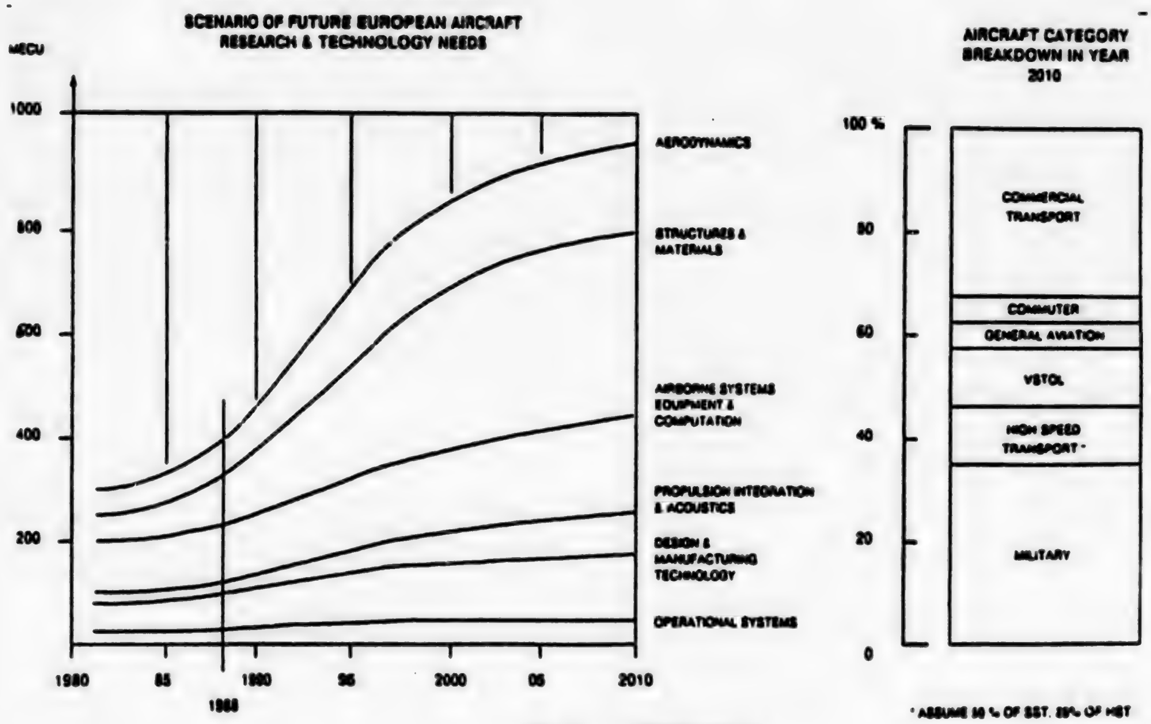
4.26. In addition to research on technologies and materials themselves there is a growing need, in the context of the 1992 market, to ensure that there is an adequate research base for the development of common norms and standards in the field of industrial technologies and materials, including notably in respect of lasers, membranes, new materials in general, fracture mechanics, construction materials and production technologies. This is in addition to the preparatory work on IT and telecommunications standards referred to earlier.

European Action

4.27. It is important that industry itself should be encouraged to invest more in the RD that is required in the areas outlined above. National authorities clearly have an important role to play in providing the right framework conditions. Community cost-sharing programs are also of significance. The very high rate of subscription to the Community programs (on the average there are 5 times more good proposals than can be funded under the present conditions) indicates that European industrialists increasingly recognize the need for R&D and are ready to participate and contribute with company funds to at least half the cost of Community-managed pre-competitive R&D on industrial technologies and materials. A new program of Community support for industrial technologies and materials has recently been proposed to the Council, which aims to provide a European dimension and to act as a catalyst to the research discussed above. As noted above, a specific effort within Europe is needed on superconducting materials.

4.28. Providing and stimulating financial commitment by industry is not, however, of itself sufficient to maximize the benefits of R&D. Two other things are also required, which would benefit from a European dimension:

- Action needs to be taken to improve the availability of skilled research managers in industry. It could be useful to examine further what action the field of training might be appropriate at a European level, whether inside or outside the Community framework;
- Top management of industry as well as research managers, must be more directly involved in R&D projects, which ought to be closely integrated in corporate strategies. The independent panel which recently evaluated the BRITE program has made such a recommendation in respect of projects financed under the Community's own programs. The positive results of such involvement have already been witnessed in the case of the ESPRIT program and in the preparation of the Commission's proposal in the aeronautics field.



(Source : EUROMART Study)

Table 4.5.

Aeronautics

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 65-66

[Text]

The Market Situation

4.29. During the period 1980-86 the European aeronautics industry captured 23 percent of the civil and 27 percent of the military world market. The world market is expected to expand substantially up to the end of the century and increasing competition to capture it must be expected, not only from the United States but also from Japan and industrializing countries such as Korea and Brazil. The United States industry remains in a particularly favorable position, however, because it enjoys a large home market and it benefits from the spin-off from military R&D programs.

The Challenge for Research

4.30. The aeronautical industry depends heavily on advanced technology to ensure competitiveness, incorporating progress in aeronautics, the design of complex structure and advanced materials, electronics, etc. as well as the design and implementation of new manufacturing methods. The development of these technologies requires a long-term strategic approach, while their application necessitates a broad industrial base.

European Action

4.31. If Europe is to be able to meet the challenge in an increasingly competitive environment a broadly-based transnational collaborative effort in R&D is now required (Table 4.5.). The Commission has recently proposed a pilot program at European level. This would provide a firm foundation for cooperation between the European aeronautical industries, and between them, universities, national research centers and SMEs. It would also enable specific urgent research projects to be tackled right away. The main technology areas identified for pilot phase are: aerodynamics and flight mechanics, materials, acoustics, computation, airborne systems and equipment, propulsion integration and design and manufacturing technologies (Table 4.5.). Special attention will be paid to safety and environmental aspects, as well as common norms and standards.

Life Sciences, Technologies

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 66-71

[Text] 4.32. Developments in the life-sciences open up possibilities that straddle the concerns of economic success and social need; ranging from improvements in

agricultural and industrial productivity that are environmentally "clean"; to progress in pharmaceuticals, chemistry and medical science; to improved understanding of the brain, with implications not just for medical science but for the design of computers; to new knowledge about the mechanism of evolution itself. Their major economic contribution could be to shorten production processes and increase efficiency in the pharmaceuticals industry; to speed up the development of new strains of plants (it took 50 years from 1930-1980 to increase the yield of corn by 70 percent through a long process of genetic selection; the same improvement could now be obtained in a few years or less); and to develop and produce products in new ways (computers built with biological components may be able to deliver vastly higher performances than current technology allows).

For convenience, the issues for research discussed below are treated predominantly in the context of Europe's economic needs, with medical research along dealt with separately in the context of the needs of European society. But it should be remembered for example, that genome analysis, which is discussed below, will be of major significance in the context of medical diagnosis and therapy as well as in bio-industries and agriculture; while certain aspects of medical research (medical instrumentation) are of relevance in the context of competitiveness and technological independence.

The Market Prospects

4.33. In both the United States and Japan biology and its applications have been identified as fields of major potential significance to industry over the period to the end of the century; and there is a widespread expectation of a rapid growth world-wide of application technologies (cf Chapter I), although determination of future market size and timing is particularly difficult. A cooperative analysis of 11 market forecasts to 2000 undertaken in 1984 showed a range of between 9 billion dollars for the least optimistic and over 100 billion dollars for the most optimistic[28]. The uncertainties have not changed in the meantime, although there is a broad consensus that pharmaceuticals, agriculture and food-processing offer the greatest market opportunities. One reason for the difficulty is the pervasive nature of the potential application of biological research; another is the speed of change in this field, which has been made possible by the development of instrumentation based on advanced physics, chemistry, informatics and mathematics.

Research Needs

4.34. Europe has pioneered many of the most important developments in the life sciences, from the discovery of the "double helix" to monoclonal antibodies and receptor-targeted pharmacology; from biological application of physical spectroscopy to the crystallographic study of the three dimensional structure of nucleic acids and proteins including, quite recently, those associated with membranes; from the regulation of gene expression to genome structure and predictive medicine.

In spite of its many achievements, however, Europe is inferior to American in breadth and depth of coverage and in the capacity to expand rapidly in new fields and to exploit the results in industry.

4.35. In several areas of biology, Europeans have found it useful to complement existing collaboration with the rest of the world (and especially with the United States) by improved collaboration among themselves. The European Molecular Biology Organization and the European Molecular Biology Laboratory, as well as the Basel Institute of Immunology are particularly significant examples.

4.36. Taking into account the ongoing and planned activities of these organizations and suggestions made by the authorities of some Member States and by university and industry researchers, 4 areas of research merit particular attention in Europe:

- **basic plant biology;**
- the molecular investigation of the genomes of complex organisms;
- neuroscience, and;
- biotechnology based agro-industrial research and technology development

Basic Plant Biology

4.37. The new tools associated with progress in modern genetics and biotechnology now make possible a diversity of potential applications for the improvement of crop sciences, for environmentally safe land use and disease control methods. But it has become apparent world-wide that the bottleneck to progress lies less in the absence of adequate application technologies, and more in large gaps in our basic understanding of key structures and functions within plants. European biotechnology has now reached a stage where the ability to manipulate plant genes, largely established by pioneering laboratories in several Member States, has outstripped the knowledge of many underlying biological functions and metabolic properties.

4.38. In order to make significant advances in biotechnology, it is therefore essential to go back to the investigation of plant physiology, using all the new tools developed for molecular investigation. If major efforts are made, it may be possible within 5-10 years to identify, for example, the "quality" molecules of many plants—those associated with innocuity, flavor, nutritional value, and texture. If they can be identified, their synthesis controlled, the "Quality" molecules would make a real difference to agricultural production, providing the basis for a better balance between high quality and low quality crops. At the same time it will be easier to establish a better balance between "bio-natural" and chemical practices in agriculture, enabling increased

production to be based on biological supply of chemical fertilizers and pesticides. Finally, better understanding of basic biology would enable closer monitoring of the interactions of crop plants with other species, which would permit better ecological monitoring of land use.

This work is of particular importance in a global context. In order to feed a world population, which could be as high as 10.000 million in 50-60 years time, without at the same time increasing the greenhouse effect, new methods of food production will be needed. Efforts must be stepped up now to provide a solution to the problems that will face Europe and the rest of the world in the longer-term future.

4.39. A major effort in this field would be at the crossroads between molecular biology, physiology and genetics. Such a multidisciplinary approach requires elaborate integration of work programs which could be achieved at the desired level of excellence only through coordinated transnational action.

Genome Analysis

4.40. Each of the 10 trillion cells in the human body contains about 100,000 individual genes. The sum total of these genes corresponds to what is known as the human genome. Knowledge of the human genome is as necessary to the continuing process of medicine as knowledge of human anatomy has been for the present state of medicine. The major diseases which affect human beings all have genetic components; and many diseases result directly from one or more defective genes. Understanding the entire genome sequence would allow a more rapid identification of these disorders and an accurate detection of hereditary predispositions. In the field of **agriculture and industry** the molecular investigation of important microbial plant and animal species is an essential complement to the work needed on basic plant biology discussed above.

4.41. The necessary research work is complex. It consists of several phases, involving respectively the detailed and physical mapping of genomes, the development of automated techniques for large-scale cloning and sequencing, and finally, the sequencing itself.

4.42. The importance of this field has been recognized outside the Community. In Japan a major effort is being made on the automation of mapping and sequencing techniques; while the United States is setting aside $3.5bn for work on the human genome during the next 10 years.

4.43. Europe has many of the skills and resources to make a major contribution to the international efforts on complex genome analysis. Already some actions are under way at a national level (France, UK, Germany, Italy). However, even the largest European country cannot work on its own in this costly endeavor. The Community as such already has experience in the field of genome analysis (the Community BAP program has involved some 24 laboratories in the sequencing of the yeast chromosome). Other discrete steps have been taken using existing programs or new proposals under the Framework Program, to organize transnational research on small-scale sequencing projects; and new efforts will be made under the Predictive Medicine initiative. Given the cost and complexity of genome analysis, further work in Europe requires transnational effort.

Neurosciences

4.44. The past few decades have seen an explosion in knowledge of the nervous system. In the past many disciplines such as medical science, physics, chemistry, and molecular biology studies the nervous system in isolation from each other. But neuroscience today is an alliance of disciplines applied to this most complex branch of the life sciences.

4.45. Even with the considerable amount of information already accumulated on what the brain is made of, what it looks like and how its elements behave, the really big questions about, for example, how man remembers, feels and carries out voluntary movements, remain unanswered

4.46. The applications of knowledge in this field go beyond pharmacology, psychology, psychiatry and medicine. The neurosciences are increasingly interesting also in terms of information theory and technology. The brain has capacities for information storage and processing, including plasticity, adaptivity, learning and creative association which cannot be matched by the best computers available at present. Mathematicians, physicists and biologists hope to build computer models that go much further than today in mimicking some of the skills of real brains.

4.47. To that end, and to ensure a timely and original first European contribution to this rapidly developing field, the Commission launched the BRAIN initiative on adaptive intelligence and neuro computing.

This latter initiative needs to be followed by other action at a European level to pool resources and complementary skills.

Industrial and Agro-Industrial Applications

4.48. The European pharmaceutical industry has enjoyed rapid growth in the 1980s, with production almost doubling between 1980 and 1987 and imports low. But it now faces a number of problems. These include the high cost (around 100 million ECU) of developing and bringing to the market a new product or chemical entity (NCE); the short period of exclusiveness granted under existing patent protection legislation (it takes usually over 10 years from the time of patent application until a marketing authorization is obtained); and increasing competition from the U.S. and Japanese industries. European research is still highly effective but the results achieved in Japan in particular (19 NCEs out

of 56 introduced in 1987) demonstrate that a redoubling of effort is required and more investment is essential.

4.49. There is also a need for further efforts in the agro-industrial field, where the Commission has already made proposals for action at Community level.

The funds estimated necessary for the program proposed on agro-industrial research (ECLAIR) are limited (80 MECU for 5 years). They allow a reasonable start, but—if successful—they are likely to need expansion in the coming years to meet the expected needs. Industry has suggested, moreover, that the currently proposed program on improved food technology (FLAIR—25 MECU over 5 years) should be complemented by an action at European level to stimulate research on **nutrition.** A new look at nutrition is desirable given the importance of the nutritional aspects of health and the possibilities offered by new technologies for food production. This "new nutrition" is being pursued in the United States and Japan in particular. In Europe the implications for transfrontier trade in food products, for the CAP [Common Agricultural Policy], and the need for common standards would need to be considered.

Energy

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE inEnglish 29 Nov 88 pp 71-76

[Text]

The Market Requirements

4.50. An adequate supply of energy at reasonable cost in the right place at the right time is fundamental to the proper functioning of industry, commerce and transport and to the satisfaction of human needs for heating, cooking and travel. Technologies that supply energy, as well as those that ensure its most efficient use are truly "enabling" technologies, without which our economies and societies would rapidly break down.

4.51. The future energy needs of the European Community up to the end of the century and alternative ways to satisfy them have been extensively analyzed by the services of the Commission with the help of national experts and the modelling tools developed under the Community's non-nuclear energy R&D program. The range of scenarios they present are a good starting point to identify research needs.

The range of figures reflects uncertainties about future economic growth, the future price of oil, emission controls, the size of nuclear power programs in individual Member States and progress in development and use of new and renewable energies.

All the scenarios point to a growing demand for **electricity,** which could rise to as much as 20 percent of the energy used by the final consumer in 2000, compared with around 15 percent today. Beyond 2000 too the demand for electricity is expected to grow more quickly than other fuels.

Table 4.6. Scenarios for Community Energy Needs in 2000 a.d.

	Mtoe	EUR-10
	2000a.d.	1985
Primary Energy Demand	1036-1218	942
Solid Fuels	229-309	218
Oil	430-539	413
Gas	196-256	182
Nuclear	150-235	116
Hydro, Geothermal, Solar, etc.	21-22	12

Source: Energy 2000, CEC 1986

4.52. The broad conclusions from this analysis—supported national studies and those of major energy companies, and reflected in the Community's agreed energy objectives to 1995—are in favor of **diversification** of European supply and **increased efficiency of energy use** as a means to ensure energy and economic security.

The close relationship between energy production and use and the **environment** add a further and compelling argument in favor of diversification. In order to minimize the negative environmental effects of each energy source it is important to have access to several solutions.

Research Needs

4.53. Many of the technologies are available now; some will only be available in the longer-term as a result of major research efforts. Those efforts, which in some cases will not bear fruits for 10-20 years or even longer, must not be weakened or abandoned simply because the price of oil in the short-term has dropped to less than half its value in the early 1980s.

In the past few years there has been some reduction in of expenditure on energy as a whole inside and outside Europe. This applies particularly to research on new and renewable energies and on fast breeder reactors as well as fossil-fuel based technologies. Expenditure on nuclear fission research continues to be the largest element in public expenditure on R&D as a whole (Table 4.7.).

Table 4.7 (con't)—Comparison Between Public R&DD Expenditures in 1987 ($ 1987) (% of the total)

	EC	Japan	US	Comm R&D	Comm R&DD (incl. JRC)
	%	%	%	%	%
Energy	9	4	8.0	3.3	8
Hydrocarbons	3	5	2.5	1.4	7
Coal	9	11	10.5	2.3	12
Nuclear Fission	39	44	33.0	7.8	20
Renewable Energies	9	5	7.0	9.7	11

Table 4.7.

MARKET REQUIREMENTS FOR ENERGY TECHNOLOGIES IN DIFFERENT TIME SCALES

	Up to 2000	Between 2000 and 2020	After 2020
National Use of energy	Energy conservation and energy use technologies (buildings, industry, transport) combustion technologies **	**	*
Electricity	Storage Conversion and transportation **	**	***
Oil	Exploration-Exploitat. ***	assisted extraction ***	**
Gas	Exploration **	conversion into liquid fuel e.g. alcohols et al ***	**
Coal	improved -exploitation and uses -fluidised bed combust. **	- Coal gasification - Combined cycles - electricity generation **	MHD gasification/liquefaction ***
Nuclear	Safety waste disposal decommissioning **	2nd generation nuclear reactors with improved safety features **	Breeder and Fusion reactors ***
Renew. Energies	Cost reduction: Solar Wind Biomass Hydraulic Geothermal *	Cost reduction : Photovoltaic solar *	Cost reduction **
Energy-Environment	Emission Reduction, radioactive waste and emission control SO_2, NO_x, (CO_2) CO_2 abatement ***	CO_2 ***	CO_2 ***

Potential market in primary energy requirements : *** > 30 % - ** 10 to 30 % - * < 10 %.

Table 4.7 (con't)—Comparison Between Public R&DD Expenditures in 1987 ($ 1987) (% of the total)

	EC	Japan	US	Comm R&D	Comm R&DD (incl. JRC)
	%	%	%	%	%
Advances Nuclear + Fusion	21	28	18.0	73.0	41
Others	10	3	21.0	2.5	!
Total	100	100	100	100	100

4.54. The reduction in support for energy R&D reflects progress accomplished since major programs were launched in the aftermath of the 1973-74 "oil crisis"; problems encountered in bringing some projects to successful technological or commercial development; and shifts of priority in publicly-financed research away from energy and towards information and industrial technologies. There remain areas where a significant level of effort needs to be maintained because of their longer-term potential for providing environmentally benign and independent sources of energy supply and use in Europe. This is particularly the case of **controlled nuclear fusion** and for carefully targeted actions in the field of **non-nuclear energies**. As far as nuclear fission energy is concerned the main needs lie more in the field of public acceptability rather than in production technology itself. The issue of acceptability and safety is discussed separately in part 2 of this chapter.

Controlled Nuclear Fusion

4.55. Nuclear fusion should provide ultimately an environmentally acceptable, practically inexhaustible, geographically independent source of energy. The economic aspects are impossible to define precisely at the present stage, but will need to be periodically monitored as the fusion and long-term energy scenarios become better known. The environmental aspects will also deserve continuous study as fusion programs approach the technological stage.

4.56. Fusion research is already a major European collaborative venture under Community auspices. This

long-term project, embracing all the work carried out in the Member States, is designed to lead in due course to the joint construction of prototype reactors with a view to their industrial production and marketing. Two third countries (Sweden and Switzerland) have joined the program. A multi-annual program for the period (1.1.1988-31.1.1992) has recently been approved. A new Program Decision should be taken in January 1991, which will need to be prepared by in depth analysis not only of the outlook for fusion itself, but of the role it could play in the energy and environmental scenarios for the next century, both within the EC and world-wide. In particular, the global climate change study (discussed later) should indicate the acceptable limits to fossil fuel combustion. Analysis will also be needed of the prospects for nuclear fission waste disposal. Both results will help to define the long-term role to be played by fusion.

4.57. Scientific wisdom, technological skill and managerial efficiency have made of the EC fusion program a recognized success. Scientific and technical achievements place Europe in the forefront of world-wide magnetic fusion research:

— JET, the flagship of the Community fusion program, is the world's largest experiment, which has made a large step towards the demonstration of the scientific feasibility of fusion;

— the European medium-size devices in operation contribute also to the progress of fusion, and the construction and commissioning of new devices are proceeding according to schedule;

— European industry is building all these devices and has already been entrusted with some long-term advanced development.

This leading position of the Community fusion program makes Europe an appealing partner for international collaboration both in bilateral frameworks (Canada, Japan, USA) and within multinational organizations (OECD, IAEA). In particular, under IAEA auspices, an agreement on participation by EURATOM—together with the United States, the USSR and Japan—in the conceptual design activities for an International Thermonuclear Experimental Reactor (ITER) has recently been signed.

4.58. The EC decision to concentrate on magnetic rather than inertial confinement has so far proved judicious: on a world-wide basis, the inertial approach should, however, not be neglected (Table 4.8.). Two-thirds of efforts, in the United States for example, are devoted to magnetic confinement and one-third to inertial confinement (which has a direct connection with military technology).

Suggestions to develop the inertial confinement approach, either by lasers or by heavy particles, have been made in Italy. Development of this approach would be at least as expensive as the present magnetic confinement program.

Table 4.8. (con't) Various Approaches to Controlled Fusion Research

Approach	Configuration	Line
Magnetic Confinement	Toroidal	Tokamak
		Alternative Lines: i) Stellarator ii) Reversed Field Pinch iii) Others
	Open	Mirror Others
Inertial Confinement	Lasers	
	Light Ion Beams Heavy Ion Beams	
Other Approaches	Muon-catalyzed fusion and fusion with exotic fuels, are sometimes also considered as a remote possibility.	

- At present, the Community funding for fusion R&D amounts to about 200 MioECU per year, corresponding to an overall yearly expenditure of about 450 MioECU. An increase of the order of 100 MioECU/year will be necessary during the detailed design of the Next Step (1992-1994). A further increase will be required during the construction phase; its amounts will depend upon the frame in which the construction will take place.
- Europe is concentrating on magnetic fusion (only 2 percent expenditure devoted to inertial fusion, because of military implications), and within that approach: 80 percent expenditure are devoted to tokamaks and 20 percent to alternative lines (no research on open configurations).
- For comparison: the U.S. fusion program follows both the magnetic confinement approach (two thirds of expenditure) and the inertial confinement approach (one third). Within the magnetic approach, open configurations have recently been abandoned (a large mirror device has been moth-balled) and U.S. magnetic research is—like in Europe—putting emphasis on tokamaks.

Non-Nuclear Energies and Energy-Saving Technologies

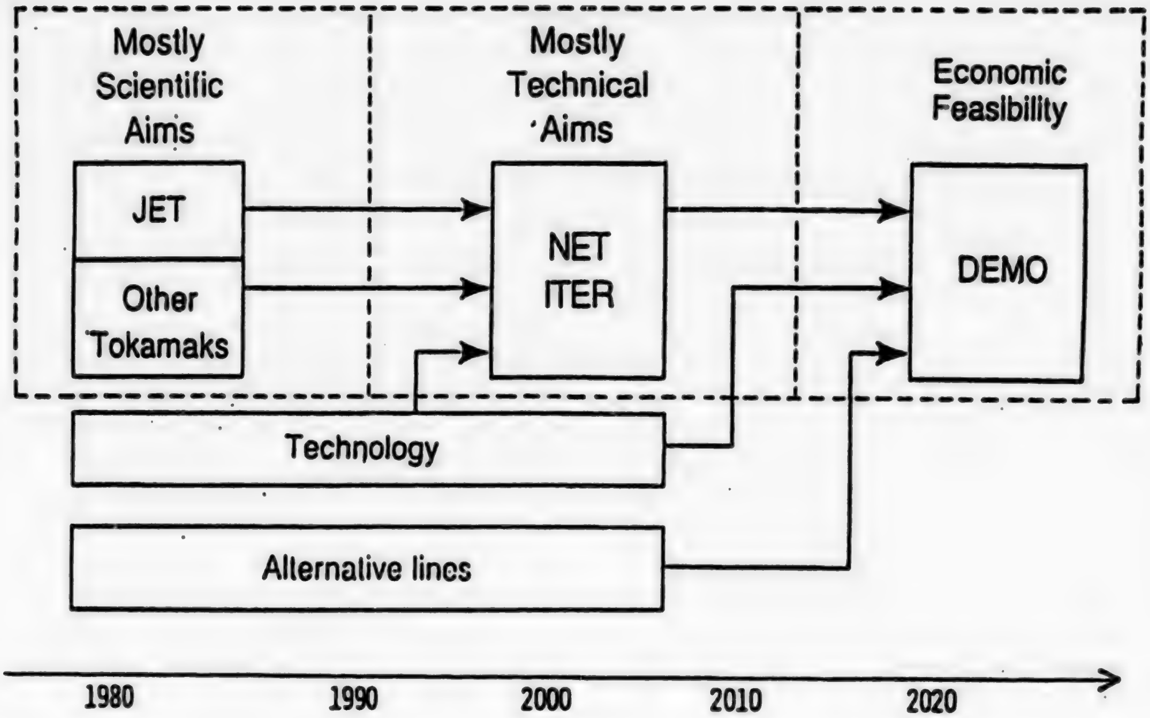
4.59. Progress on non-nuclear energies has significantly evolved since research activities throughout the Community were stepped up from the early 1970s. The three successive Community programs on energy R&D, together with the Community's demonstration programs, have made an important contribution to this development in Europe and throughout the world.

The present state of research can be considered under four main headings:

(i) Renewables

Solar power plants using photovoltaic cells have good long-term prospects provided the costs for the cells and the

Table 4.8. European Fusion Program Strategy



THE THREE ABOVE-MENTIONED STEPS TOWARDS FUSION REACTORS (DEMONSTRATION OF SCIENTIFIC, TECHNOLOGICAL AND ECONOMIC FEASIBILITIES) ARE INTERDEPENDENT AND OVERLAP EACH OTHER.
AT THE TIME OF THE NEXT PROGRAMME REVISION (1-1-1991), THE PHYSICS AND TECHNOLOGY DATA BASE WILL PROBABLY BE SUFFICIENT TO ALLOW TO DECIDE ON THE STARTING DATE OF THE DETAILED DESIGN OF THE NEXT STEP.

associated array structures can be reduced to about 1 ECU/Watt. Another important area is the development of passive solar technology to reduce conventional energy requirements for heating and cooling in buildings.

Wind energy research aimed essentially at cost reductions and reliability of larger wind generators. Long-term contributions of up to 10 percent of total electricity demand in some regions are conceivable.

Biomass research aimed also at reducing overall costs of collection and conversion of biomass through pyrolysis, gasification and liquefaction.

Geothermal R&D focussed on "Hot dry rock" technology development could provide heat and power almost anywhere in Europe where the geological conditions are favorable once economic feasibility is achieved.

(ii) Rational energy use

Development work is concentrating on heat pumps, advanced batteries and fuel cells. Heat pumps have the potential to reduce energy use in domestic and industrial heating by 30-50 percent. Advanced solid batteries are being developed for electrical vehicles. Fuel cells are being given particular attention in the field of energy production and storage.

Energy savings research in industry is focusing on component development and unit operations. In combustion research for stationary applications and in transport the main interest lies in the twin concerns of energy saving and pollution abatement.

(iii) Fossil fuels

One important field is the use and conversion of solid fuels, i.e. coal, peat, lignite, including the possible reduction of environmental pollution involved in the coal conversion processes. Research on liquefaction, combined cycle electricity generation with fluidized beds and coal gasification is being carried out in some of the Member States and at Community level. The use of coal/liquid mixtures is also being researched.

The bulk of hydrocarbons research is being carried out by the oil and gas companies themselves. At Community level the focus of activity is to increase the economic

exploitable reserves accessible to the European oil industry. Drilling techniques are progressing as far as speed and reliability are concerned, especially in the deep and off shore drilling sectors. The same holds for production techniques including assisted recovery.

(iv) Energy modelling

A fourth important research area embraces the analytical tools essential to understanding energy systems and their interface with the economy and the environment. This is an area where the value of coordinated activities among different research institutes and universities in a Community framework has already proved its worth (cf. Energy 2000 study cited earlier).

Future Options

4.60. Some of the technology options which were pursued in the aftermath of the first "oil crisis" have now come to an end from the point of view of research, because they have reached their goals and led to practical exploitation (one example is passive solar water heating which is now relatively widely developed in Europe, notably in Southern Europe).

Others have come to an end either because of specific technological problems encountered or because, for economic reasons, they do not offer the prospect of broad application. One example of the former is solar tower power stations.

On the other hand, new perspectives have emerged in the light of the trends described earlier. These are summarized in Table 4.9. The new targets are reflected at Community level in the Commission's recent proposal (the JOULE program).

Table 4.9. Priorities for Non-Nuclear Energy R&D

Rational Energy Use (RuE):

- Energy savings in buildings (energy management and control, heat pumps, solar energy applications);
- Combustion technology (computer simulation of combustion, experimental verification with advanced non-intrusive diagnostics);
- Industrial processes (heat recovery including development of heat exchangers and heat pumps, unit operations, energy and process system models);
- Fuel cells (solide oxide, molten carbonate) high Tc superconductors, energy storage.

Renewables:

- Wind energy (large-scale installations, wind measurements and modelling);
- Photovoltaic solar energy (crystalline and amorphous silicon technology);
- Hydraulic energy (small hydro, study of potential of tidal and wave energy);
- Biomass (production and storage of energy crops, biological and thermal conversion, pilot projects);
- Geothermal energy (hot dry rocks, brine handling and corrosion and scaling of resources, study of deep geology)

Energy Derived From Fossil Sources:

- Oil exploration and recovery techniques;
- Conversion of gas into liquid fuels;
- Combined cycle electricity generation with fluidized beds and coal gasification;
- New solid fuel burners;
- Magneto-hydrodynamics

Modelling Energy and Environment:

- Energy resources, energy supply and demand systems;
- Energy/environment interactions;
- Assessing impact of the Single European market on energy/economy.

2. Improving Quality of Life for Europe's Citizens

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 p 77

[Text] 4.61. European science and technology have a major contribution to make in three main areas:

- in producing a better **environment**;
- in improving **health**; and
- in enhancing **safety**.

In addition there are important social responsibilities which must be addressed in the field of **bioethics**, which are considered separately below.

Environment

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 77-80

[Text] 4.62. There is increasing public awareness about the threat to the environment. Political leaders have responded to such concern and have proposed specific national, regional and international actions. The relevance of the European dimension has been formally recognized by the Single European Act, which identifies the protection and the improvement of the environment as a main objective of Community action.

4.63. Environmental problems are complex, in continuous evolution and incompletely known. Research provides therefore a vital basis on which policy responses can be evolved.

Though many problems are common to industrialized countries, and others are "global" in the literal sense of the word (namely they concern the whole globe and require world-wide collaboration), many probiems are of

a regional nature. Moreover, the European Community has regulatory responsibilities which must rest on sound scientific knowledge and reliable technical know-how. Joint research at Community level is therefore needed to provide this knowledge and know-how efficiently and economically (through complementarity and task sharing), and also to provide it in a form acceptable to all concerned.

Research Needs

4.64. The research problems to which need or would greatly benefit from research at a transnational level in

Europe are summarized in Table 4.10. They form three interdependent sets:

- **Understanding the basic phenomena;Detection and interpretation of environmental changes;**
- Prevention.

Table 4.10. Key Research Issues in the Environmental Field

A. Understanding the Basic Phenomena

- mechanisms of climate;
- atmospheric (troposphere and stratosphere) chemistry ("ozone hole");
- physiology or organisms under environmental stress (pollutants, drought, etc);
- functioning, stability and vulnerability of ecosystems, including stress ecology, natural population dynamics;
- metabolism and effects of xenobiotic substances in man, animals and plants;
- interactions between atmosphere, soil and water bodies;
- chemistry and biology of soil under the influence of pollution and other stresses (eg. agricultural practice), vulnerability to erosion;
- basic mechanisms of seismic and volcanic events;
- study of the effects of pollutants on materials;
- research into the prevention of accidents from hazardous industrial activities.

B. Detection and Interpretation of Environmental Changes

- improvement of methods for the analysis of the components of environmental matrices;
- earth observation by remote sensing techniques;
- elaboration of methods for storage and treatment of data on the environment, also in support of modelling;
- collection, compilation and assessment of data on environmental quality;
- description and evaluation of damage symptoms on organisms;
- epidemiological studies in human populations exposed to environmental pollution;
- recording of indicators for climatic changes.

C. Prevention of Environmental Damages

- development of sound technologies for pollution abatement and waste recycling and disposal;
- development of alternative, less polluting technologies and products ("clean technologies");
- methods for the ecologically sound management of ecosystems and renewable resources;
- rehabilitation of disturbed or degraded ecosystems;
- development of safer technologies (chemical plants);
- investigation of the possibilities to predict, and to mitigate the consequences of, disasters of man-made and natural origin;
- design of methods and materials for the protection and restoration of the cultural heritage.

Understanding the Basic Phenomena

4.65. Since the environment results from the complex interaction of many complex sub-systems, these must each be analyzed (the stratosphere, the atmosphere, soil, inland water, the sea), and their mutual interaction studied by a systems approach (large ecosystems, climate in its regional as well as global aspects). In addition further efforts are needed to understand the environment within buildings, an area on which the Community's JRC is carrying out pioneering work.

A scientific approach to a system of this complexity would have been unthinkable a few decades ago. However, progress in basic mathematics, analytical techniques (including remote sensing from space), together with the huge capacity to store and analyze information by advanced computing now make this approach possible.

Detection and Interpretation of Environmental Changes

4.66. A second set concerns the continuous detection and interpretation of environmental changes and the assessment of their consequences on human, animal and vegetable life as well as on geological resources and the sea. This is needed to provide public assurance that undesirable trends will be detected and also to provide data for the analysis outlined in 4.65. above.

Environmental epidemiology is included in this activity. The advantages of a European dimension in terms of statistical significance are obvious. Environmental toxicology and the development of suitable systems to identify and measure noxious agents is also important.

Prevention

4.67. The third set concerns prevention, including the development of clean technologies, the abatement of existing noxae and the elimination of toxic wastes. Research on the safety of industrial practice and compatibility of agricultural practice with the environment also belongs to this group. Since these activities are continuously evolving, so must the research itself. Studies on the prevention and mitigation of man-made and natural hazards also be long under this heading.

Global Climate Change

4.68. The greatest source of concern and the most difficult to analyze is the so-called "greenhouse-effect."

Continued burning of coal and oil since the beginning of the industrial era has resulted in increasing quantities of carbon dioxide being added to the natural composition of the planet's atmosphere. Although the oceans act as a large sink through complex phenomena involving phytoplankton photosynthesis, large quantities of carbon dioxide remain in the atmosphere, which is now enriched in this gas by 15-20 percent with respect to preindustrial values. Natural recycling of CO_2 by green terrestrial plants is also seriously impaired by deforestation.

Carbon dioxide is not transparent to the infrared light radiated back by the earth's surface as a result of incoming solar radiation, which means that heat is trapped in the lower layers of the atmosphere. The planet is thus being heated in a similar way to that of a greenhouse.

Scientific consensus is that such heating will produce an increase in the global mean surface temperature of 1.5 to 4.5 degrees C over the next 50 years. The atmospheric accumulation of other greenhouse gases, such as methane, nitrous oxide and the chlorofluorocarbons also plays a role.

The climate change resulting from such heating would have serious consequences for agriculture, and a significant rise in the level of the seas is expected from the thermal expansion of the oceans alone, apart from the melting of the ice caps.

4.69. The issue has global dimensions and is made enormously complex by the uncertainties still affecting the measurement of global heating, the regional and seasonal features of the anticipated climatic changes (precipitation patterns, frequency of droughts and other extreme events, etc.), and the uncertainties about future energy patterns. It involves an assessment of the rates of carbon dioxide production, of the role of the oceans and biosphere as sinks and sources, of the rate of deforestation, the possible shifts of bioclimatic zones, the modelling of all the interactive components of the climate systems (atmosphere, oceans, cryosphere, biosphere), and an appreciation of the consequences of energy policy options.

4.70. Intensified research is needed to reduce as much as possible, and as soon as possible, the remaining uncertainties, especially as regards the timing, the magnitude and the regional distribution of climate change; the impacts which the change would have mainly on agriculture and water resources, on the sea level and its consequences for the coasts and coastal-based economic activities, on socio-economic structures in general; and on environmentally benign energy options capable of leading to reduced carbon dioxide emissions. At the same time research is needed to ensure preparedness in respect of changes which cannot be prevented in time, so at least alleviate their consequences.

4.71. Such research requires European and world-wide cooperation, not only because of the multi-disciplinary character of the issue, but also in view of the need for a coordinated approach to choices that might have to be made on future energy, agriculture and industry policies and on measures able to counteract or alleviate the affects of the climate change.

European Action

4.72. At a European level the Community will need to mobilize various modes of action to satisfy research needs for the understanding, monitoring, protection and improvement of the environment, starting from its own "in house" research carried out in the JRC (a guarantee of independent high level S/T know-how for the whole Community), to a shared-cost action and international collaboration.

In the latter context a major contribution at the Community level to the implementation of the International Geosphere-Biosphere Program (Global Change) deserves careful attention.

At the same time an adequate liaison needs to be assured with other transnational environmental R&D actions in Europe, and notably within EUREKA and with the space agencies (in particular with ESA) to ensure a proper balance between the space instruments themselves and the requirements of the scientific community (see also point 4.106. on Earth sciences).

Health Research

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 80-82

[Text]

Research Needs

4.73. Three main issues in the field of health provide the starting point for consideration of research requirements:

(i) **the rising cost of health care and delivery systems.** Health costs in the community amount to more than 200 billion ECU per year, the equivalent of about 8 percent of GNP. They are rising both because of the increasing sophistication of medical equipment and opportunities for treatment, and because of the growing incidence of certain diseases. This is related in part to:

(ii) **the "greying" of Europe's population.** Europe faces the prospect of an ageing population over the period to

the end of the century as a result of lower reproduction rates in the 1970s and 1980s, on the one hand, and higher life-expectancy, on the other. This will mean a quantitative increase over coming years in age-typical illnesses, with consequences for the demand on medical services;

(iii) the need for major progress in the fight against diseases such as **cancer and AIDS**, as well as those related to the environment and life-style.

4.74. Public health research in the Community, which is about half that of the United States, amounts to less than 2 percent of total health costs. If properly aimed, it can make a major contribution to meeting all three of the needs described above. Research on prevention, care-delivery systems and organization is essential to ensure the best value for money in health delivery (i); while the need for targeting research efforts on the specific problems posed under (ii) and (iii) is widely recognized.

European Action

4.75. Research is proceeding on all these fronts in the Member States, but often in a fragmented manner. Most national research programs in the field of medicine and health consist of a large number of relatively small projects carried out by scattered and relatively small research teams often working independently at universities, hospitals etc. This is an area where the value of more coordinated action across national frontiers has already been recognized and concerted action within the Community framework has proved its worth. The principal characteristic of this concerted action is that Member States themselves select the projects for coordination at Community level and execute the work themselves; while the Commission coordinates the national research contributions.

4.76. The future action lines in health research recommended by the Advisory Committee for the Community's Health Research Program are summarized in Table 4.11. It will be seen that they correspond very clearly to the needs described earlier.

Table 4.11. Future Action-Lines Planned in Health Research

CANCER:

—Cancer research training scheme
—Clinical treatment research
—Epidemiological research
—Early detection and diagnosis
—Drug development
—Experimental (fundamental) research

AIDS:

—Disease control and prevention
—Viro-immunological research
—Clinical research

AGE-RELATED HEALTH PROBLEMS:

—Reproduction
—Ageing and diseases
—Disabilities

ENVIRONMENT AND LIFE-STYLE RELATED HEALTH PROBLEMS

—Breakdown in human adaptation
—Nutrition
—Consumption of illicit drugs
—Infections

MEDICAL TECHNOLOGY DEVELOPMENT:

—Diagnostic methods and monitoring
—Treatment and rehabilitation
—Technical and clinical evaluation

HEALTH SERVICES RESEARCH:

—Research on prevention
—Research on care delivery systems
—Research on health care organization
—Health technology assessment

They also include one important aspect of R&D on health research—the development of medical technology—which has an economic as well as social dimension.

Safety

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 82-84

[Text] 4.77. The safety of the environment in the home, at work and in travel is a fundamental social need, linked also to the control of costs in health. The contribution of R&D to safety is pervasive—from the use of new materials to the development of robotics, from the improvement in vehicle and aircraft technology to the development of monitoring and sensing techniques to identify potential dangers in the environment and in machinery and equipment long before they occur.

Industrial and Road Safety

4.78. In the field of **industrial technologies and materials** increasing attention will have to be given to the safety aspects of design of consumer goods and also to the safety of the working environment itself, as foreshadowed in the Single European Act itself. An important issue, where R&D has a role to play, is the development of common safety standards in respect of the new technologies themselves. Lasers for industrial use are a significant example.

4.79. The potential contribution of R&D to **road safety** in the longer-term is particularly great, and major efforts are being undertaken in Europe to develop both the "intelligent car" and the road infrastructure that it will

require. This is an area where collaborative transnational efforts are important both because of the scale of the research requirements and the need for a harmonized approach. The Community itself has launched a significant program (DRIVE—Dedicated Road Infrastructure for Vehicle Safety in Europe) which is designed to help coordinate efforts on the infrastructure; while within EUREKA the PROMETHEUS project and other related transport R&D projects are focussed on the in-car research requirements. Coordination of effort is a major preoccupation.

Nuclear Fission Safety

4.80. A third area where continuing safety research is of the utmost importance is **nuclear fission.** The dependence on nuclear power for energy supplies varies significantly as between Member States. But as the Chernobyl accident demonstrated forcefully, the safety of nuclear power is a matter that concerns each and every Member State.

4.81. The United States used to be in the forefront of research but the Americans have now reduced their efforts. Japan is continuing to make a significant effort. The results of Soviet work in the field are not fully available, although some opening has occurred after Chernobyl. Europe has moved into the forefront, with some countries playing a leading role (France, Germany, and the United Kingdom).

4.82. In the field of **radiation protection** (where Community research programs have either directly supported or coordinated 80 percent of the effort inside the Community) continuing research is needed on:

— Human exposure to radiation and radioactivity (measurement and interpretation of radiation dose; transfer and behavior of radio nuclides in the environment, making full use of the information coming from Chernobyl).

— Effects of the human body of exposure to radiation; assessment, prevention and treatment

— Management of risk of exposure to radiation.

4.83. A major information effort is also required. In the aftermath of Chernobyl, political and social considerations overrode scientific and technological arguments about radiation levels and their effects. Scientists and technologists are partly responsible for this. Before the event they underestimated the importance of systematic information and education of the public; while after the event they confused the public by non-homogeneous technical jargon and disagreements about details. This has had negative consequences in some countries on public confidence in the nuclear community. This confidence can and must be restored by greater openness and willingness to communicate, not only in terms understood by fellow scientists, but also in terms accessible to a much wider public progress. Particular efforts must be made in this direction over the coming months and years.

4.84. Continuing research work is also needed on reactor safety (notably the phenomenology of low probability severe accidents; mitigation of the consequences of severe accidents; structural behavior of reactor components; fuel behavior; improved passive safety mechanisms); the safety of the fuel cycle; radioactive waste management and storage; decontamination and dismantling techniques for nuclear plants; and control of fissile materials.

Bioethics

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 p 84

[Text] 4.85. The progress in biology described earlier is so rapid and the resulting applications so pervasive and substantial that the utmost attention must be given to their impact on individuals and society. Ever since biotechnology began to open up major new possibilities, notably in the field of genetic engineering, biologists themselves have been conscious of this need. More than a decade ago they proposed and implemented a moratorium on genetic engineering research until the conditions for safety were identified. Since then, public opinion as well as public authorities has become progressively aware of the problem and bio-ethics has become a subject of constant attention and action, not only at the national but also at the international level (for example the yearly Bioethics Conferences of the Summit of industrialized countries). In Europe itself, the Council of Europe has created a standing committee for bioethics.

4.86. The Community's obligations in the field of health and safety, as well as the need (for competition reasons) to avoid the emergence of widely divergent legislation in the Member States on biotechnological applications and products are compelling reasons for a Community approach to this issue. Such an approach would contribute to public confidence in science in the Community, without which the European Technology Community cannot be soundly built.

In the first half of 1988 the German Presidency of the EC Council, in complete agreement with the EC Commission, called for the pursuit of bioethics at Community level. Some progress has been made. The momentum should be maintained and increased. It is essential that ethical, societal and juridical considerations accompany science and precede technological developments.

3. Fundamental Research— Essential Underpinning

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 84-90

[Text] 4.87. A solid capacity in fundamental research, both free and targeted, provides the essential underpinning to the research in specific fields described above. As the provider of new ideas and knowledge it offers opportunities for quantitative change and new openings of both economic and social significance, widening and deepening the scope of technology options. It is therefore of vital importance to Europe's quest for independence and autonomy.

4.88. In the United States, while Federal support for non-military applied research and development has decreased, that for fundamental research has increased over the last 5 years (cf. chapter 2). Japan is now fully aware of the need to strengthen its basic research at home, and in an international framework has, for example, launched the Human Frontier Science Program for joint development of fundamental research in neuro- and cell biology by the Industrialized Summit Countries. In the United States scientific research proceeds on a very broad front, and gives opportunity to "free," individual choices, whereas in Japan targeted basic research prevails. The implications of this new international emphasis on basic research are discussed further in Chapter 5.1. below.

4.89. European excellence in fundamental research is demonstrated by the attribution of Nobel Prizes and by the other indicators of performance discussed in Chapter II. However, most European researchers would think that the United States occupies the first place in their own field[29]. During the last decade, industry and universities have become increasingly aware of each other. The questions posed by the further evolution of this trend in Europe are also discussed in Chapter 5.

The Organization of Basic Research

4.90. One permanent problem for basic research policy is the distribution of resources between a small number of large and expensive projects (so-called "Big Sciences") and more diffuse and less expensive activities of small groups and individuals.

The question has been partially solved in Western Europe by several multinational ventures for the common pursuit of Big Sciences (eg. CERN for high energy physics, ESO for astronomy, ESA for space, EMBL for biology, ILL for neutron sources, ESS for synchrotron radiation[30]). Moreover, some very large national facilities, such as the German center in Hamburg are open to bilateral collaboration. These activities have been successful and there is growing collaboration among them, which is a welcome trend. In the future, international collaboration in Big Sciences may have to extend worldwide. Controlled nuclear fusion is a case in point as discussed earlier.

Simultaneously, several networking initiatives have been taken so as to assure the benefits of complementarity and task sharing among individual scientists and small groups. The European Science Foundation (ESF), the European Molecular Biology Organization (EMBO) and the European Community's Stimulation Program (now called the SCIENCE Program), together with the Community's sectoral R&D programs, play important roles in this context.

There remains, however, the question of access to advanced middle-size research devices and the development of expensive scientific instrumentation. Given the cost and sophistication of many of the facilities in question it is not feasible to imagine that they could all be available in every European country, let alone very major laboratory. Particular efforts are therefore needed to provide a framework for cooperation among national teams and to reduce the risk of fragmented research efforts. In 1989, in recognition of this problem, the Community will initiate a pilot program to support mutual access to large national installations. Suggestions have also been made within CREST to launch a feasibility study on joint European Development of scientific instrumentation.

Developments in Specific Scientific Disciplines

4.91. Within the broad area of fundamental research, some developments in mathematics, physics, chemistry and the earth sciences should be highlighted. Fundamental biology, together with basic biotechnology and its applications was dealt with earlier in Section I.

Mathematics

4.92. In modern mathematics, the theory of non-linear phenomena and related geometrical ideas deserve attention because they are revolutionizing the theory and applications of dynamic systems, with far-reaching implications for physics, chemistry, biology, meteorology, ecology, technology and, probably, sociology and the science of economics. Most real world problems are complex and non-linear; therefore they fall outside the scope of traditional closed-form analysis. The subtle and versatile techniques of dynamic systems theory now make it possible to model and to explore the evolution over time of both natural and man-made systems.

4.93. The combination of theoretical advance and significant computing power now makes it possible to distinguish those systems which evolve towards a stable solution; those that evolve to a situation of stable oscillation; those that reach alternative final states depending on small differences in the initial conditions; and those that develop into a state of steady but perpetual chaos. The search of an underlying order in the ensemble of all

chaotic trajectories in a chaotic system remains a major challenge to modern mathematics.

4.94. Specific examples of the impact which the theory of nonlinear, complex phenomena has on other branches of science and technology include the development of the first optical version of a transistor, and demonstration of the feasibility of an all-optical computer; advanced modelling of climatic change (of relevance to the Global Change initiative discussed earlier); improvements in the functioning of the internal combustion engine.

4.95. The theory of non-linear phenomena was pioneered in Europe. And Europe continues to play a significant role. Research projects in fields such as those mentioned in 4.94. above are amongst those accepted, after stiff competition, under the EC Stimulation program, reflecting the continuing interest of European researchers in pushing out the frontiers.

Physics

4.96. In addition to encouraging further collaboration among existing multinational ventures in high energy physics etc., greater attention needs to be given tc the exploitation of technology spin-offs. This must be done without side-tracking the main projects. The scope for closer links with EC technological research programs and to the industrial firms participating in them could be usefully explored.

4.97. As far as fundamental physics are concerned, particular attention needs to be given to the study of condensed matter, because of both its implications for materials technology and its need for large and medium scale investigation facilities (such as synchrotron radiation and neutron sources, high power lasers, irradiation devices). The United States and Japan are well provided with such devices. In Europe, however, they are often unique and, (as suggested above), could be open to increased transnational use.

A suggestion along these lines was made in 1985 by the UK Sciences and Engineering Research Council and could be pursued through the EC program of Access to Large Installations.

4.98. Among the scientific developments of particular interest in terms of the expected technological impact, is **high temperature superconductivity** (the ability of electrical currents to flow without resistance), which was discussed in Section 1 above in the context of industrial materials.

4.99. Other areas of the physics of matter should also be mentioned, because of their electromagnetic, optical or mechanical properties, such as "low-dimensional" (i.e. very thin) materials, artificially structured materials, material obtained and performing under extreme conditions, liquid crystals, quasi crystals. Progress on these subjects has a high priority in the United States.

4.100. Developments in optics and lasers are also interesting: in advanced optics, Western Europe is in a good position and has pioneered some recent developments (for instance, the Joint European Optical Bistability Project with the EC Stimulation Program).

In lasers, however, in spite of some important national and multinational developments inside BRITE and EUREKA, European efforts are not on a par with those in the United States, where there has been a significant spin-off from military R&D, and notably SDI. The need for strengthened joint European action in this field merits careful consideration.

Chemistry

4.101. Chemistry is also developing rapidly, "pushed" by progress in computing, mathematics and physics instrumentation and "pulled' by biology and by a pervasive market demand.

Here as in other technological areas, quality is becoming more important than quantity. From the scientific standpoint, computer modelling and prediction as well as progress in analytical tools[31] are changing the way in which chemicals are isolated, identified, designed by computer and synthesized. Progress in the theory of chemical reaction is leading to a whole spectrum of new catalysts (synthetic enzymes, catalytic surfaces, cluster catalysis, homogeneous catalysis) and photochemically primed events. At the same time a number of techniques, including "intelligent" selection membranes are improving separation and purification.

4.102. Europe occupies a very good position both on the market for chemistry-based products (see Chapter I) and in basic science. There are, however, some problems of public acceptance because of the issue of toxic waste. Possibly related to the latter, there is also some difficulty in recruiting a sufficient number of high quality students (cf. Chapter 5).

Earth Sciences

4.103. The importance of progress in the earth sciences for the prediction of natural phenomena with major economic and social impacts (eg. earthquakes), as well as for the rational exploitation of land resources goes without saying.

4.104. The oil companies, in particular, are themselves engaged in significant basic and applied research. Deep drilling has been pioneered by the Soviet Union; and there are major efforts in the United States. Good European coordination is assured by the European Science Foundation (cf. the Geotraverse Project supported by the EC). At a national level, the German government recently decided to initiate a very ambitious program to drill a very deep (10 km) hole through the crust of the earth. This is important because other deep drills (notably those carried out in the Soviet Union) have

suggested that conventional methods in exploration of the earth crust may be affected by artifacts.

4.105. Oceanography, as part of the earth sciences, is being actively pursued throughout the world. The United States is leading the field, with a high level of participation of Japan and some European countries. Some aspects such as the study of the coastal zone, the interface between the ocean and the atmosphere (important for understanding global climate change) will be pursued by the Community's MAST Program and the complementary EUREKA project EUROMAR.

4.106. Earth observation from space constitute in the next decade a new and unique source of data essential for progress in earth sciences. Earth observation satellites generate information which, by virtue of its synoptic, uniform and repetitive nature, can help to contribute to more efficient management of the Earth's resources, better monitoring of the environment and global climate change, as well as accident management (oil spills, forest fires, etc.). This is discussed further in annex 11, which deals more generally with the opportunities offered by space techniques. Close cooperation with space agencies, and in particular with ESA, will be necessary to ensure a proper balance between space missions and the requirements of the scientific community as well as coherent European participation in international programs. Furthermore, the use of space data will be conditional on the timely development of data interpretation methods and techniques, which will require enhanced cooperation and support at European level.

The role of the Community in Fundamental Research

4.107. The need for fundamental research in Europe is met partly by national actions; partly by the specific transnational agencies established in specific fields; and partly by actions at Community level (the SCIENCE and large Installations programs; the more fundamental parts of specific and more targeted programs; and the ERASMUS and COMETT programs, which help to prepare the future development of science and its transfer to industry). The Community programs bring to national actions the added value of complementary competencies and a wider cultural space, without seeking to substitute for work undertaken by other agencies. Particular efforts need to be made, however, to ensure the best possible coordination with the work of other agencies so as to avoid any risk of duplication and to ensure the greatest possible degree of industrial spin-off from the programs of others.

V. Key Issues for Science, Technology Policy in Europe

Overview

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 p 91

[Text] 5.1. Alongside the analysis of future research needs (Chapter IV) there are also a number of other important issues for public policy on science and technology which will need to be addressed as Europe moves further along the road in the creation of a Technological Community.

The Commission considers 10 broad issues to be of particular importance. These relate to the balance and organization of research itself at national and at European level; education, training and information throughout Europe; the role of industry and the private sector; policy coordination and cohesion within Europe, and cooperation with third countries.

Balance, Organization of Research

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 91-94

[Text]

(I) The Balance Between Basic and Applied Research

5.2. As discussed in Chapter III, the pressures for improvements in the industrial fabric, combined with public expenditure constraints, have led to a shift of public resources in some countries towards the support of applied industry-oriented R&D with a potentially short pay-back period and a corresponding reduction in support for more fundamental research.

5.3. Such a readjustment was inevitable given the perceived inability of Europe to translate basic invention into commercial success. But there is a risk that the pendulum will swing too far in this new direction just at a time when our competitors are placing themselves a greater emphasis on basic research as the provider of new knowledge and longer-term technological and commercial opportunities. It was noted earlier that the one area in which Federal spending on civil R&D has increased under the present U.S. Administration is that of basic research. Japan too is now making vigorous efforts to develop its own capacity in basic research, recognizing that technological development is dependent on and increasingly interdependent with mastery of fundamental research. OECD Science and Technology Ministers meeting in Paris in October 1987, moreover, agreed that one of the key tasks of governments in science policy was to "provide the science base necessary for economic growth and for social and cultural development, and especially to **support basic research**" (Commission emphasis)[32].

5.4. This is a matter for all European governments to reflect upon. In many areas basic research is very expensive. This is obvious for fields like high energy physics or oceanography or space. But many smaller-scale basic research investigations now also require high-cost sophisticated equipment. Costly basic research cries out for a joint coordinated approach whether through the sharing of expensive facilities or the formulation of coordination work programs. Resource-pooling is

already happening to some extent in Europe, notably through CERN, EMBL, ESO, the basic research program of ESA and ESF[33]. The SCIENCE program of the Community is also helping to demonstrate the usefulness of joint approaches to speculative basic research. And in ESPRIT II and under the new BRITE-EURAM program currently before the Council provision has been made for joint projects on more targeted basic research topics than hitherto.

5.5. The Commission believes that this trend should be reinforced during the coming years. It considers basic research to be an essential aspect of Community efforts, underpinning research aimed at improving competitiveness and research on societal problems facing Europe. Basic research supports industrial development longer-term alongside—but distinct from—shorter-term product development. Basic research also performs the vital function of "training" researchers in the paradigms, methods and norms of research. To neglect this human capital would seriously compromise Europe's long-term prospect. As suggested in Chapter IV, biology is one field where new fundamental research efforts are now needed to lay the foundations for more applied research later, notably in the fields of health and agriculture.

Private industry should also be encouraged to invest more in basic research for the longer-term. Historically, important advances in fundamental research have been made by scientists working within private sector companies (one example is the work on beta-blockers which recently led to the award of a Nobel Prize to Sir James Black).

(ii) The Links Between Industry and the Universities

5.6. The Japanese technological success is partly attributable to close relationships between universities, industry and government, including the establishment of a series of specifically cooperative ventures involving firms, universities and MITI laboratories[34]. In the United States industry-university cooperation dates back over many years, but in the 1980s it has witnessed a qualitatively new development in the form of major multimillion dollar contracts between companies and universities enabling companies to be the first to have access to the work carried out on campus in a broad scientific domain and for a period of years[35]. In Europe the traditions of industry-university links vary considerably but the general trend has been towards a reinforcement, with industry driven increasingly by the need to tap scientific knowledge and universities by financial constraints. One associated phenomenon has been the growth of "science parks" on both sides of the Atlantic (eg. Durham in the United States, Cambridge in the UK). Community cost-sharing programs such as ESPRIT and BRITE have aimed to encourage the links by deliberately providing a framework in which industry research workers and those in universities can team up in specific R&D projects.

5.7. The trend towards close industry-university links in Europe should be further encouraged. It is one more potential means of maximizing the use of scarce R&D resources. But there are two caveats. The first is linked to the balance between basic and applied research (point (i) above). There is a risk that increasing university dependence on industry may encourage more and more university resources to be devoted to short-term problem-solving to the neglect of longer-term and more fundamental research. Secondly, there is a risk that exclusive relationships between companies and universities or university departments may lead to restrictions on the availability of research results. This is already an important issue in the United States, and it is likely to grow in importance in Europe. Already the OECD, in a recent report has expressed concern about the implications for the longer-term[36].

The Commission has shown the way to avoid the risks in Community programs through the nature of the contractual arrangements made with participants, which provide a basis for both assuring the dissemination of research results to interested parties while safeguarding the interests of the specific research groups involved. But this is an issue which will need to be considered further in all research funding programs of a national as well as a transnational nature.

5.8. Two other more specific developments at a European level also deserve attention in the context of links between universities and industry. The first is the creation by a number of multinational companies of a European Institute of Technology aimed specifically at creating links between industrial R&D efforts and pre-competitive university research. The second is the growing industrial interest in participation in the multidisciplinary collaborative research associations in Europe known as European Laboratories without Walls (ELWWs). This latter issue is currently under discussion by the Community's Management and Coordination Advisory Committee on Biotechnology and by the Industrial Research and Development Advisory Committee (IRDAC).

Basic research must be given adequate support and attention, if solid foundations for the future are to be constructed.

Industry-university links should be further encouraged, but attention must be paid to the consequences for the nature of university research work and the availability of research results.

Education, Information

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 94-97

[Text]

(iii) Broadening and Deepening the Technology Culture

5.9. The conduct and management of research and the application of the technologies that result from it all depend on the skills of individuals. The most successful societies in the post-war period have been those that have sought actively to develop those skills, to create a general climate of technology literacy and to encourage the emergence of large numbers of highly trained scientists and engineers. In the future these skills will be ever more in demand.

5.10. Japan has witnessed the most significant growth in general technical literacy and in the numbers of research scientists and engineers. In the United States the numbers are high but stagnant, and increasingly worries are expressed about the future availability of the manpower needed to carry through the new technological revolution. In Europe the traditions of some countries are stronger (Chapter II) than others. But there are widespread mismatches between the output of traditional education and the demand for skilled manpower. There are particular shortages of highly qualified scientific personnel in the smaller and less developed countries of the Community (see (viii) below). But even in some of the larger countries the shortages of science-based skills are already a source of some concern and there are new worries about a "brain-drain" as U.S. universities and companies seek to entice the brightest and the best to meet their own future needs for highly qualified scientists and engineers. The U.S. drive will not be directed only at Europe: a key issue in the United States now is whether and how to encourage the large number of Asian students at U.S. universities to stay on in the United States. But Europe will continue to be a major potential source of supply of highly trained research scientists to the United States.

5.11. The question of science education, training and skill acquisition is one principally for national governments. Industry also has an important role to play and many industries have already increased their own training efforts as a partial solution. But the value of complementary action at Community level has already been demonstrated by the success of the COMETT and ERASMUS programs. Alongside, the Community must now move forward in improving the attractions of the wider European framework to the most able national research workers by more rapid progress in creating a genuine **Researchers' Europe.** As the scope of research needs widens and deepens it is less and less possible for individual countries, however large, to offer centers of excellence in every field. It becomes in consequence increasingly important for researchers to be able to take advantage of the possibilities offered by the whole European Community. At present the mobility of researchers is hampered not only by language problems, but also by practical problems such as different social security systems, pension arrangement and so on. Progress in this area will be greatly facilitated by the removal of barriers to the free movement of labor within the Community in the framework of progress towards the Community's Internal Market.

(iv) The Public Acceptability of Science and Technology

5.12. A related issue is that of public acceptability of science and technology. Public concern has two facets. On the one hand, people worry about the **dangers** and **risks** associated with new technology, and particularly the possibility of involuntary accidents (a repeat of the Chernobyl accident, the escape of dangerous biological cultures, the possibility of major chemical spillages etc.). On the other, there is **ethical concern** about the possibilities offered by scientific developments, for example in the field of genetic engineering, which may be voluntarily exploited.

5.13. Concern about new scientific developments is often based on fears of the unknown. This is particularly true at present in the case of biotechnology. Public opinion surveys in the United States and in some European countries have revealed considerable confusion about its benefits and risks. They have also demonstrated that the degree of acceptability of new technologies such as biotechnology depends heavily on the level of general education and on the depths of understanding of the issues surrounding a particular scientific development or technology[37].

It is important for the proper functioning of our democracies and for the advance of European society that popular understanding of the issues should be improved. Only in that way will sensible choices be made; a sound regulatory environment established to minimize the risks; and an informed basis created for examination of the ethical issues. The role which information can play in this respect is visibly illustrated in the case of the Netherlands where tough regulations on safety matters combined with a high quality, extensive and systematic provision of public information in schools and through the mass media has helped to reduce concern about recombinant DNA techniques.

5.14. The Commission has a role to play on behalf of the whole Community in improving public understanding about these important issues by help in the design and development of consistent and objective information material. The prospect of a large expansion of satellite broadcasting could offer new opportunities for Community-backed programs on science and technology issues.

More attention must be paid in Europe to the development of human resources, both to pursue scientific knowledge and to apply its results. A particular effort must be made to provide an attractive environment inside Europe for research workers in which the brightest and the best have easy access to the centers of excellence which are available in different countries.

At the same time a particular effort must be directed to improve public understanding of science and technology issues.

Industry, Private Sector

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 97-100

[Text]

(v) Encouraging the Private Sector To Invest More in R&D

5.15. A major challenge for Europe is to increase the share of its economic resources that are devoted to investment in R&D, which for the bulk of European nations is well below that of the United States and Japan (Chapters II and III). Much of the efforts must be made by industry itself, which has been the leading source of the growth of funds in non-military R&D expenditure in the United States and Japan. It is in industry's own interests to invest more in R&D as the source of longer-term improvements in competitiveness and profitability. But the growth in industry-funding of R&D is not profitability. But the growth in industry-funding of R&D is not uniform across Europe. Industry-funding of R&D must be focussed not only "downstream" on projects of short-term commercial benefit. Japanese and U.S. industry is spending more and more money on targeted basic research to create the conditions for longer-term advance. European industry must do the same.

5.16. Factors of importance in encouraging investment in R&D and innovation include the general economic climate, tax regimes, and (for innovative investments) the existence of developed venture capital markets (the latter being of particular importance to nascent or small companies). In Europe overall rates of industrial investment vary widely; each country has its own system of tax or other incentives to support industrial R&D; while venture capital markets (which are developed in the United Kingdom, and to a lesser extent in the Netherlands and Belgium) are essentially national markets.

5.17. The Community's R&D programs on industrial technologies (ESPRIT, BRITE in particular) have already played a role in helping to commit industry-funding of R&D through cost-sharing mechanisms. A number of initiatives at European level have also been taken to encourage investment by small and medium-size enterprises. **The European Venture Capital Association** (ECVA) was created in 1983 with the support of the Commission. In collaboration with ECVA the Venture Consort project aimed at promoting transnational financing of innovation in SME's was launched in 1985. The Commission has also recently approved the launching of an initiative for financial support for the establishment of "seed capital" funds and for a European network of such funds.

The barriers to transnational industrial and technological cooperation have already been analyzed separately in a separate communication by the Commission, which contains an action plan[38].

The Commission is also exploring with the financial community whether it would be appropriate to establish one or several investment companies specialized in this kind of project. It is also exploring with the insurance companies the most appropriate way to insure the risks involved and thus to remove one of the main obstacles to invest in innovative projects. These two initiatives (**Eurotech Capital and Innovation Insurance Facility**[39]) aim to ensure the industrial and commercial application of the results of European R&D programs.

In addition, the European Investment Bank has made available loan finance to SMEs, with priority for innovative investment, using its own resources and those of the New Community Instrument (NCI). Between 1985 and 1987 its loans for investment in high technology amounted to 1,094 million ECU. The proposed NCI V includes investments in high technology as one of the two priorities areas.

The Commission is also working towards improvements in the flow of information between potential financiers and the promoters of projects who are seeking external finance, by establishing a project data-base.

5.18. Alongside action to improve the flow of private funds to industry the Commission has operated competition policy in such a way as to balance the need to increase the overall level of investment in industry in R&D against that of avoiding distortions to competition. A specific framework has been established for the handling of joint agreements between enterprises in R&D and for state aid regimes for R&D projects. As the Community moves further towards the completion of the Internal Market, with a consequent increase in competition, on the one hand, and concentration, on the other, the application of competition policy to R&D and particularly to transfrontier R&D arrangements will become an increasingly important issue.

(vi) The Diffusion of Technology

5.19. R&D itself lies at the center of a complex feedback process involving education (upstream) and innovation and diffusion or technology transfer (downstream). As well as investing more in R&D, industry also has to know and understand the new technologies coming on the market and to invest directly in them. An expert group of the OECD has recently noted that "the economic advantages of new technologies derive from their diffusion rather than from their refinement.... New technology in itself has hardly any economic advantages as long as it is not effectively used and widely applied...."[40]. The sluggish growth in European demand for electronic goods (chapter 1.2) is one important example of the slow rate of adoption of new technologies. It should also be said that the benefits of research to develop those technologies are also enhanced the more widely they are disseminated, even though this may not always be in the immediate commercial interest of an industrial firm or research consortium.

5.20. Technology transfer is another area where the Japan is in a stronger position than Europe. In some European countries (notably Denmark) major efforts have been made in recent years to encourage the spread of new technologies within industry and commerce through information campaigns and specific financial support systems for the private sector. But the degree of attention varies. Moreover,the public policy efforts are based essentially on the spread of technologies within national borders.

Effective dissemination of the results from the Community's own research activities contributes to the goal of improving information. This is the purpose of the VALUE program. But the impact of measures in this field is directly related to the volume of Community research activities. This is why complementary actions such as those carried out under the SPRINT program to create more favorable conditions for innovation and technology transfer will need to be reinforced in the future. Outside experts have recently underlined the importance of a vigorous effort in this direction and called for a strengthening of the SPRINT activities[41], and a new and larger program has now been proposed by the Commission.

The importance of stimulating demand for new technologies cannot be overstressed. A key issue is the availability of information about particular technologies and their expected returns. Organized "watch" programs have proved to be very; efficient in Japan. Consideration needs to be given in Europe to how to improve this information and to stimulate the consumer (of capital or consumer goods) to think about how new technologies could help satisfy his needs.

The role of Member Governments and the Community in standardization and normalization of technologies is also important in the context of shaping the market for adoption of technologies.

Industry must be encouraged to invest more in R&D, and top management should be more closely involved than is often the case.

A major effort is needed throughout industry and the services to improve awareness and information about new technologies so that the fruits of R&D can be widely and quickly spread.

Policy Coordination, Cohesion Within Europe

36980123 Brussels FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE in English 29 Nov 88 pp 101-103

[Text]

(vii) Increasing Coordination Among National Policies

5.21. Chapter III underlined the importance of increased coordination of national policies as a means of saving money overall, increasing the returns to R&D investment, encouraging the broadest use in the Community of "best practice" in research management, and ultimately leading to greater complementarity in national programs. This is why Article 130H of the Single European Act expresses a political commitment on the part of the Community's Member States, in liaison with the Commission, to coordinate among themselves their policies and programs at national level.

5.22. The first step in better coordination must be to ignore mutual information and understanding about national policies. Such information about what others are doing will in itself contribute to future decisions on national programs or policies. The second is to identify fruitful areas for more specific cooperation. These can be of a bilateral or multilateral nature. Some may be appropriate to Community-wide coordination. There are numerous formulas possible for developing cooperative activities (such as specific as bilateral or multilateral agreements, joint agreements on national participation in major projects such as CERN, EMBO, or supplementary programs in a strictly Community framework as provide for under Article 130L of the Single European Act). At Community level the formula of "concerted action" at, which has proved highly successful in the fields of health and environment and which requires a minimal amount of Community public funding, should be more widely used.

(viii) Improving the Cohesion of the Community

5.23. The technology gap between the less-favored regions (LFRs) and the more economically advanced areas of the Community is greater even than the economic gap (Chapter III). In most LFRs there is a lack of physical infrastructure for research and development; there is a chronic shortage of skilled scientific personnel; companies are less oriented towards innovation. Improving the RTD base is essential to ensure adequate growth and development in the LFRs.

5.24. The better coordination of national research activities will certainly have some spin-offs in regional terms. And the Community's value program will ensure the spread of research results throughout all the regions of the Community, helping to reinforce the knowledge base in the LFRs. Moreover, the Community's own research programs have already promoted relations between researchers in LFRs and their colleagues elsewhere, encouraging the "trickling down" of best practice and experience. But substantial improvements in regional competitiveness cannot be tackled primarily through Community research programs themselves. The main principle applying to the choice of research projects for Community support is that of excellence in scientific terms, and the evaluation of projects and programs is based on purely scientific criteria. Excellence is a goal which is appropriate for all regions to strive towards. But scientific excellence will not be achieved everywhere without major improvement in the RTD fabric.

5.25. To achieve these improvements mechanisms other than research programs themselves must be used. At a Community level new opportunities are offered by the reform of the Community's three structural funds, whose budget will be doubled by 1993. Actions needs to be focussed on infrastructure; stimulating innovative activities in industry; helping companies and institutes to prepare for participation in Community programs; and technical assistance and evaluation. The Commission is already contemplating one specific action known as STRIDE[42]. This is not a research program aimed at specific research goals. Nor is it a blueprint for RTD development prepared centrally. In keeping with the philosophy applying to the structural funds it is a framework for the development of initiatives to improve the RTD base in LFRs in partnership with the regions themselves. Other actions through the other structural funds may be considered.

5.26. It would be illusory to believe that the problem of the technology gap within the Community can be rapidly and easily bridged. Infrastructural development; training; the creation of and innovative capacity, all take time. But action through regional and social policy instruments will help to shorten the time-scales involved.

Better coordination of national policies would help to save money and improve the efficiency of resource use throughout the Community.

At the same time a particular effort is required to improve the RTD fabric in the less-favored regions of the Community. Research programs in themselves cannot provide a complete answer. A major action using regional and social policy instruments is needed.

External Aspects

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[Text]

(ix) Encouraging Cooperation in RTD With Third Countries

5.27. Science and technology are increasingly international commodities. At the level of the firm there has been a rapid growth in recent years of cooperative ventures in R&D, often of a transnational nature. Among universities and between them and industry, relations of a transnational nature are already common. There is a growing international market in research scientists. And national policy-makers have recognized the value of access to the scientific and technological resources of third countries as a means of providing the new knowledge and expertise needed to sustain growth and development in their own countries. In the case of Europe there are particularly intensive scientific exchanges and significant industrial R&D cooperation with the United States.

5.28. By committing the Community to develop RTD cooperation with third countries and international organizations, Article 130G of the Single European Act recognizes the importance for Europe's own long-term future of properly coordinated action in this field. The recent recommendations[43] of the OECD Council also urge Member States in their own mutual interests to promote scientific and technological exchanges. The further internationalization of RTD is therefore inevitable. The issue is how best to organize international cooperation in such a way that it can be a "positive-sum" game in which all the participants have something to gain.

5.29. For the European Community cooperative activities must be focussed principally on three groups of countries, to whom different considerations apply, namely: other countries within Western Europe, and notably our **EFTA partners**, the other **industrialized countries outside Europe**, and the **developing countries.** Outside these three groups separate reflections are now needed on the basis for cooperation with the Soviet Union and Eastern Europe in the light of the new relationships now developing across the European continent; as well as on policies of RTD cooperation with the NICs that take into account, on a case-by-case basis, the position and prospects for individual countries.

5.30. As far as the **EFTA** countries are concerned, cooperation has been running since the establishment of COST in 1971. COST remains an important framework for cooperation on specific projects " la carte" with other European countries. The Luxembourg agreement of 1984 between the Community, the Member States and the EFTA countries to create a European Economic Space has led to an intensification of relations in the scientific field. Special bilateral cooperation agreements have now been concluded between the Community and 5 of the EFTA countries. The sixth (with Iceland) has recently been submitted to the Council for approval. These agreements provide for various forms of access to Community programs. Alongside the Community framework EUREKA provides a useful basis for cooperation between companies and institutes from the EFTA countries (and Turkey) and those from the Community Member States themselves.

5.31. Cooperation within a strictly Community framework with **industrialized countries outside Europe** is less well-developed. At a commercial level, as noted above, a dense network of linkages in R&D between companies has been established across the Atlantic. Moreover, the tradition of transatlantic migration of European scientists goes back a long way. But these developments have occurred in the absence of a formal general framework for cooperation with the United States. It might now be appropriate to explore the scope for such a general

framework, given the wealth of U.S. resources and experience in the scientific domain and the opportunities and issues raised by the recent developments in the United States described in Chapter II. It would also be timely to take advantage of the new moves by Japan towards the international science and technology community in order to examine seriously the scope for mutually beneficial cooperative ventures which are unlikely to exacerbate commercial strains.

5.32. For the **developing countries** the situation is different again. Their problems are, in some respects, akin to those of the less-favored regions of Europe, but their shortages of RTD infrastructure and skilled scientists and skilled manpower are more severe. These limitations in terms of indigenous resources put a powerful brake on economic and social development. In addition many of them face specific problems in the fields of agriculture, medicine and health, and the environment which require a particular research effort.

Europe has considerable experience and expertise in these research fields, partly as a consequence of colonial experience. But the expertise is often fragmented among different national institutes. Efforts are needed to coordinate national actions.

Some of the necessary coordination is already underway at Community level. Since 1983 the Community has been running with the LDCs a program of R&D directed as the problems of tropical medicine and agriculture ("Science and Technology for Development"). Separately, since 1984 it has developed a flexible program of scientific cooperation in Latin America, Asia and Mediterranean countries aimed at the integration of research workers in these countries into the international scientific community, the improvement of indigenous research capacities, and, latterly, exploring the scope for technology transfer.

These programs are an important contribution to the Community's wider development policy objectives, and in the years to come RTD must play an increasingly important role in this context. Given the growing concern about **environmental** issues in the developing countries (soil erosion, industrial pollutants etc.) and the need to optimize the development and exploitation of the **natural resource base** and new and renewable energies, there is a growing need for a particular new and coordinated research effort in these fields. At the same time the wider consequences for the developing countries of scientific advances in, for example, materials and biotechnology will need to be considered further.

(x) Avoiding Technological Protectionism

5.33. The longer-term benefits of RTD cooperation at an international level can only be fully achieved if the transfer to knowledge and technology is facilitated rather than constrained. Historically the scientific world has been an open world in which results of research are widely published and discussed and taken up and elaborated by others. But the "industrialization" of research and the growing importance of science to trade flows has increased the pressure to restrict the flow of information in order to preserve competitive edge.

5.34. This is a major issue for international cooperation, notably in the Community's relations with other industrialized countries, which has been addressed recently by the OECD in its Council Recommendation of April 1988[44]. The Commission believes that Europe and the world economy as a whole would be the loser from a more protectionist scientific and technological world. LDCs would be even bigger losers. **The Community should therefore work towards ensuring the diffusion of research results and away from policies that restrict the flow of information.** The necessary corollary is that progress should be made in ensuring adequate regimes for the protection of intellectual and industrial property. The Commissions therefore vigorously endorses the OECD Council Recommendation on the need to work towards this end.

Science and technology are international commodities, and international cooperation must be a fundamental element in European RTD policies. The Community must further cement its relations with the EFTA countries; explore new modes of cooperation with the other industrial countries, notably the United States and Japan; and build on its successful cooperation with LDCs.

One important issue affecting relations with third countries is the question of technological protectionism and potential restrictions on the flow of knowledge. The Community should work towards ensuring the diffusion of research results by third countries and away from policies to restraint the flow of information.

Footnotes

1. "Comparative Study of the Technology Level of Europe, the United States, Japan and the Soviet Union," Michel Poniatowski, President of The Committee on Energy, Research and Technology, European Parliament, 15 Jun 1987.

2. "The Economics of 1992," European Economy n°35, March 1988.

3. Market share is defined as the export of the United States, Japan or EC-IO to the rest of the world compared with exports of OECD countries as a whole to the rest of the world.

4. For example "The Contribution of Science and Technology to Economic Growth and Social Development," OECD SPT/Min(87)2, 7 October 1987.

5. "Futurible," Paris Dec 1987.

6. Borrus, M. et al. "Telecommunications Development in Comparative Perspective: The New Telecommunications in Europe, Japan, and the United States," Berkeley Round Table on Industrial Economy, California 1985.

7. For example, OECD Employment Outlook, Paris 1986 Freeman & Soete: "Information Technology and Employment—An Assessment, April 1985.

8. Where possible, data are given for the enlarged Community on the basis of estimates for Spain and Portugal. In most cases data for Luxembourg are not available.

9. "The European S/T "Space" in the International Context: Resources and Conditions for Community Competitiveness," Working paper prepared for COPOL 88, 29 Feb 1988.

10. Share of R&D spending in GDP.

11. Methods of calculating military R&D expenditure are not uniform. Official figures may underestimate Japanese military R&D spending compared with those of European countries.

12. Estimate made in COPOL study—see footnote 9.

13. It is worth noting that the U.S. figure is less than half of some estimates made of Soviet R&D personnel by the U.S. National Science Foundation (see source to table 2.3.)

14. This is considered further in recent work by Pavitt & Patel: "Measuring Europe's Technological Performance: Results and Prospects," Center for European Policy Studies, 1988.

15. Table 48 of OECD "Main Science and Technology Indicators 1981-87," Paris 1988.

16. Figures are from "Research and Development FY 1989" American Association for the Advancement of Science, Report XIII, 1988.

17. The attribution of particular projects to one category or another is subject to question: some "development" projects, for example, have undoubtedly had a more fundamental research element in them. The trend towards development is nevertheless striking.

18. "Changing America: The New Face of Science and Engineering," Interim Report of the Task Force on Women, Minorities and the Handicapped in Science and Technology, Washington D.C. 1988.

19. See, for example "Picking Up the Pace—The Commercial Challenge to American Innovation," Council on Competitiveness, Washington D.C. 1988.

20. Estimate from the 1987 White Paper on Science and Technology, Science and Technology Agencies, Japan.

21. Estimates made by EC Delegation, Tokyo.

22. The Present State of Science and Technology in Japan—Summary of the Results of the 1987 Science and Technology Research Survey, the Management and Coordination Agency, 1987.

23. "Trends and Future Tasks in Industrial Technology-—Developing Innovative Technologies To Support 21st Century," MITI, September.

24. Research and Technological Development in the Less Favored Regions of the Community (STRIDE), and STRIDE-Science and Technology for Regional Innovation and Development in Europe, 1987. Figures are from Tables 5.1. and 5.2. of the latter document.

25. See STRIDE report.

26. More detailed information on the trends in EUREKA and in the links between EUREKA and Community programs can be found in the Commission's Communication.

27. COMM(88)291 final of 24 June 1988, and in its report to the Parliament on 18 July 1988. COMM(88)291 final.

28. "High Technology Industries, Profit and Outlook: Biotechnology, U.S. Department of Commerce, International Trade Administration, Washington D.C. 1984.

29. This emerges clearly from "The Community of Science in Europe," Mark N. Franklin, a study made on behalf of the CEC in collaboration with the European Science Foundation (contract STI 042, November 1986) and subsequently published by Gower (ISBN 0566056321).

30. CERN—European Center for Nuclear Research, EMBL—European Molecular Biology Laboratory, ESO—European Organization for Astronomical Research in the Southern Hemisphere, ESA—European Space Agency, ESF—European Science Foundation.

31. Mass and optical spectroscopy, NMR—Nuclear Magnetic Resonance, ESCA—Electron Spectroscopy for Chemical Analysis, XAFS—Xray Absorption Fine Structure, XANES—Xray Absorption on Near Edge Structure, Neutron activation, neutron scattering, chromatography.

32. Communique of the OECD Committee for Scientific and Technological Policy at Ministerial Level, 28-29 Oct 1987.

33. CERN—European Center for Nuclear Research, EMBL—European Molecular Biology Laboratory, ESO—European Organization for Astronomical Research in the Southern Hemisphere, ESA—European Space Agency, ESF—European Science Foundation.

34. Notably the JISEDAI (Basic Technologies for Future Industries) and ERATO (Exploratory Research for Advanced Technology) programs. This is not to say, of course, that the Japanese experience can be directly translated to Europe.

35. Well-known examples are the 10-year-agreement between HOECHST and the Massachusetts General Hospital for the creation of a department of molecular biology; and a 5-year-agreement between MONSANTO and Washington University in St. Louis for research on proteins and peptides.

36. Science and Technology Outlook, 1988. OECD, Paris 1988.

37. See "Science and Engineering Indicators," 1987, NSF Washington; "Public Opinion on Biotechnology: (un)known, (un)loved?" in "Biotechnology in Holland," Swiss Biotech, 5(1987).

38. COM(88)114 final, du 28.3.88.

39. Formerly EUROTECH INSUR.

40. Science and Technology Policy Outlook, OECD 1988.

41. Evaluation of the first BRITE program (1985-88) Research evaluation report n°25, CEC 1988.

42. Sciences and Technology for Regional Innovation and Development in Europe.

43. Recommendations of the OECD Council about a general framework of principles relating to international scientific and technological cooperation, 21 April 1988.

44. See footnote n°31.

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